

AD-A146 095 AN INEXPENSIVE MICRO-COMPUTER FOR LABORATORY DATA 1/1  
ACQUISITION AND TEST EQUIPMENT CONTROL(U) DAYTON UNIV  
OH RESEARCH INST G A HARTMAN ET AL. JUL 84  
UNCLASSIFIED AFAL-TR-84-4889 F/G 9/2 NL

AN INEXPENSIVE MICRO-COMPUTER FOR LABORATORY DATA  
ACQUISITION AND TEST EQUIPMENT CONTROL (U) DAYTON UNIV  
OH RESEARCH INST G A HARTMAN ET AL. JUL 84  
AFWAL-TR-84-4889 E/G 9/2

1/1

UNCLASSIFIED

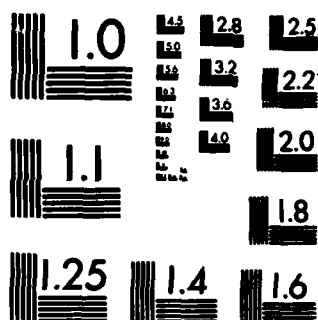
F/G 9/2

NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AFWAL-TR-84-4089



AN INEXPENSIVE MICRO-COMPUTER FOR LABORATORY  
DATA ACQUISITION AND TEST EQUIPMENT CONTROL

G. A. Hartman  
R. W. Tait

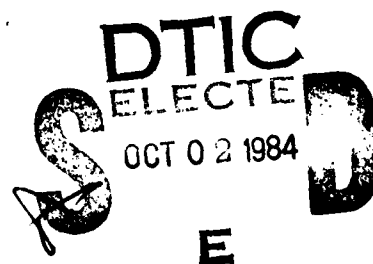
UNIVERSITY OF DAYTON  
RESEARCH INSTITUTE  
300 COLLEGE PARK DRIVE  
DAYTON, OHIO 45469

JULY 1984

INTERIM REPORT FOR PERIOD JANUARY 1983 - JANUARY 1984

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

MATERIALS LABORATORY  
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433



84 09 28 014

AD-A146 095

DTIC FILE COPY

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

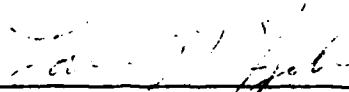


THEODORE NICHOLAS, Project Engineer  
Metals Behavior Branch  
Metals and Ceramics Division



WALTER H. REIMANN, Act'g Chief  
Metals Behavior Branch  
Metals and Ceramics Division

FOR THE COMMANDER



LAWRENCE N. HJELM, Asst Chief  
Metals and Ceramics Division  
Materials Laboratory

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify AFWAL/MLLN, W-PAFB, OH 45433 to help us maintain a current mailing list".

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

## REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			Approved for public release; distribution unlimited		
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFWAL-TR-84-4089			5. MONITORING ORGANIZATION REPORT NUMBER(S) AFWAL-TR-84-4089		
6a. NAME OF PERFORMING ORGANIZATION University of Dayton Research Institute		6b. OFFICE SYMBOL (If applicable)		7a. NAME OF MONITORING ORGANIZATION Materials Laboratory (AFWAL/MLLN) Air Force Wright Aeronautical Laboratories	
6c. ADDRESS (City, State and ZIP Code) 300 College Park Drive Dayton, Ohio 45469		7b. ADDRESS (City, State and ZIP Code) Wright-Patterson Air Force Base, Ohio 45433			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State and ZIP Code)		10. SOURCE OF FUNDING NOS.			
		PROGRAM ELEMENT NO.		PROJECT NO.	TASK NO.
				2307	P1
11. TITLE (Include Security Classification) An Inexpensive Micro-Computer for Laboratory Data Acquisition and Test Equipment Control					WORK UNIT NO. 14
12. PERSONAL AUTHOR(S) G. A. Hartman and R. W. Tait					
13a. TYPE OF REPORT Interim Report		13b. TIME COVERED FROM 1/83 TO 1/84		14. DATE OF REPORT (Yr., Mo., Day) July 1984	
15. PAGE COUNT 92					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB. GR.			
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>A versatile, inexpensive laboratory data acquisition and control unit has been developed. A VIC-20 microcomputer is used in conjunction with an expansion chassis and plug in interfaces which make it applicable to a wide variety of real time laboratory control and data acquisition tasks. A system of this type can be built for much less than one thousand dollars.</p>					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Theodore Nicholas			22b. TELEPHONE NUMBER (Include Area Code) (513) 255-2689		22c. OFFICE SYMBOL AFWAL/MLLN

# FOREWORD

This work was performed under a contract with the Metals Behavior Branch (MLLN) of the Materials Laboratory, USAF Contract Number F33615-81-C-5015, under the administration of Dr. Theodore Nicholas. Part of the contract was to provide more efficient usage of the test equipment and to enhance the testing capability in the laboratory. The electronics components which were designed and developed under this contract were manufactured and assembled by the technical staff of the 4750th Fabrication and Modification Test Wing.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



## TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>
1	INTRODUCTION	1
2	HARDWARE COMPONENTS	3
2.1	VIC-20 MICROCOMPUTER	5
2.2	TELEVISION OR MONITOR	5
2.3	EXPANSION CHASSIS	5
2.4	POWER SUPPLY	6
2.5	INTERFACE BOARDS	8
2.5.1	<u>Boards Requiring Address Slots</u>	8
2.5.1.1	Analog to Digital Converter Board	12
2.5.1.2	Digital to Analog Converter Board	17
2.5.1.3	Counter and Digital Input/Output Board	20
2.5.1.3.1	Counter	20
2.5.1.3.1.1	TTL Pulse Counting	22
2.5.1.3.1.2	Periodic Function Counting	22
2.5.1.3.2	Digital Input/Output	25
2.5.1.3.3	Board Setup	29
2.5.2	<u>Boards Not Requiring Address Slots</u>	30
2.5.2.1	Strain Gage Conditioner	30
2.5.2.2	Current Driver	34
3	APPLICATIONS	36
3.1	AUTOMATED FURNACE CONTROLLER	36

## TABLE OF CONTENTS (CONCLUDED)

<u>SECTION</u>	<u>PAGE</u>
3.2 SCHENCK RESONANT FATIGUE TEST MACHINE CONTROLLER	43
3.2.1 <u>Schenck Characteristics</u>	44
3.2.2 <u>VIC Controller</u>	44
4 SUMMARY	59
APPENDIX A - PARTS LIST FOR THE INTERFACE BOARDS	60
APPENDIX B - SCHEMATICS FOR THE INTERFACE BOARDS	67
APPENDIX C - BOARD LAYOUTS FOR THE INTERFACE BOARDS	74



## LIST OF ILLUSTRATIONS

<u>FIGURE</u>		<u>PAGE</u>
1	Expansion Chassis With Interface Boards for Schenck Control Application.	4
2	A/D Board Test Routine.	16
3	D/A Board Test Routine.	21
4	Counter Test Routine.	26
5	Digital Input/Output Test Routine.	28
6	Furnace Control Program.	37
7a	Schenck Control Program.	46
7b	Variable Definitions for the Schenck Control Application.	54
8	Machine Language Program Listing for the Schenck Control Program.	55

## LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
1	POWER REQUIREMENTS FOR INTERFACE BOARDS	7
2	SWITCH SETTINGS AND BOARD BASE ADDRESSES	10
3	REGISTER FUNCTIONS FOR THE INTERFACE BOARDS	11
4	VOLTAGE RANGE SELECTION AND INPUT CONNECTIONS FOR THE A/D BOARD	13
5	VOLTAGE RANGE SELECTION AND OUTPUT CONNECTIONS FOR THE D/A BOARD	18
6	COUNTER CONNECTIONS AND MODE SWITCH SETTINGS FOR COUNTER/DIO BOARD	23
7	DIGITAL INPUT/OUTPUT CONNECTIONS FOR THE COUNTER/DIO BOARD	27
8	FILTER CAPACITORS AND FILTER CUTOFF FREQUENCIES FOR THE STRAIN GAGE CONDITIONER	32
9	COARSE GAIN SWITCH VALUES FOR THE STRAIN GAGE CONDITIONER BOARD	33

## SECTION 1

### INTRODUCTION

Many laboratory tests and procedures require the continuous data acquisition and control of one or more process variables to maintain proper test conditions. It is often impractical to perform these functions manually 24 hours a day. Micro- and mini-computers have been purchased to automate much of the testing equipment in the laboratory. However, there are several cases where the cost of existing micro- and mini-computer systems is not justified by the intended application.

The VIC-20 system was originally developed as an inexpensive control system for the Schenck resonant machines in the MLLN Laboratory. As the capabilities of the unit became apparent, additional applications were identified and the necessary interface hardware was designed and built. At the present time, three applications have been identified and will be discussed:

1. Control of four Schenck resonant fatigue testing machines,
2. Control of a furnace used for automated heat treating, and
3. Control of data acquisition for a electropneumatic shaker system used for crack growth studies.

The MLLN Laboratory has several Schenck fatigue machines. All of these machines are over 30 years old and all of the original control systems were in poor condition. A prototype analog control system was built and

proved to be functional, however, this system was expensive to construct and install and was difficult for new operators to learn. The VIC-20 control system was developed as an alternative and has proved to be inexpensive to construct and install and easy to operate.

The automated furnace controller was designed to eliminate the need for manual 24 hour monitoring of heat treatments. Many of these heat treatments require a constant heating or cooling rate. With the existing manual controls, this required constant setpoint adjustments by the operator. The VIC-20 system allowed the operator to set up the desired heat treatment temperature profile and the computer would complete the heat treatment.

The control and data acquisition system for the electropneumatic shaker system is currently being developed. The system will control a pneumatic actuator which applies a quasistatic load to the sample. In addition, the unit will provide a DC signal to the shaker to control the amplitude of high frequency loads superimposed on the quasistatic load. Cycle counts will be monitored and stored and the operator will enter optical crack length readings. The optical crack length readings will be used to determine the appropriate load amplitudes necessary to maintain a constant stress intensity at the crack tip. Electric potential techniques may be used to provide a direct crack length measurement. Using the electric potential technique would eliminate the need of many optical crack length measurements and would totally automate the system.

## SECTION 2

### HARDWARE COMPONENTS

The control and data acquisition system is comprised of the following parts:

- VIC-20 Microcomputer
- Television or Monitor
- Expansion Chassis
- Power Supply
- Interface Boards:
  - Analog to Digital Converter
  - Digital to Analog Converter
  - Counter and Digital Input/Output
  - Strain Gage Conditioner
  - 0.1 Ampere Current Driver

A VIC-20, a television or monitor, an expansion chassis, and a power supply constitute the base system. The interface boards can be used in any combination requiring less than eight card slots in the expansion chassis. Board layouts, parts lists, and schematics of each of the boards are included in the appendices. Figure 1 shows the expansion chassis with all the boards necessary for the Schenck control application.

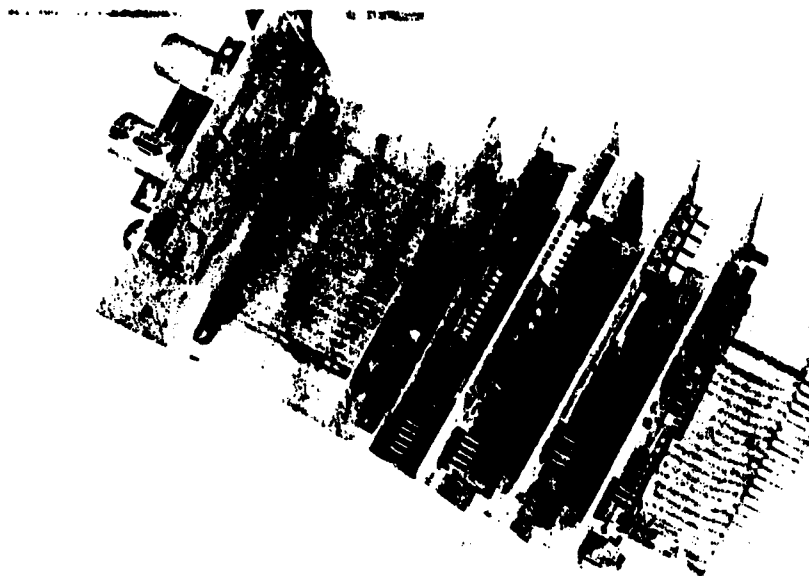


Figure 1. Expansion Chassis With Interface Boards  
for Schenck Control Application.

## 2.1 VIC-20 MICROCOMPUTER

The VIC-20 is a 6502 based eight bit microcomputer including an integral keyboard and a five volt power supply. Complete documentation of the system is available from the manufacturer in the VIC-20 programmers reference guide. All interfaces to the VIC are made via the 44 pin expansion port at the back of the unit. This interface provides data, addressing, and handshake lines as well as five volt power for the expansion chassis. See Section 2.3 for details about power requirements.

## 2.2 TELEVISION OR MONITOR

The display unit for the VIC is either a standard television or any monitor that accepts composite video signal. Interconnecting cables are supplied with the computer.

## 2.3 EXPANSION CHASSIS

The VIC expansion port provides space for installation of a single interface card. Since many applications require use of more than one interface card, it was necessary to design an expansion chassis to provide room for up to eight interface boards. The expansion chassis carries all forty-four signals to each card slot and equipment sold by the manufacturer, such as memory expansion cartridges, will work with the expansion chassis.

The internal five volt supply in the VIC will provide up to one amp of power to the expansion chassis. Table 1 shows the power requirements for each of the interface boards. If the application under consideration requires a total for all interface boards of more than one amp on the five volt supply then jumper JP-1 on the expansion chassis should be removed and an external five volt supply with sufficient current capacity should be connected to the solder posts at the far end of the expansion chassis.

#### 2.4 POWER SUPPLY

Because the VIC provides a five volt supply only, an external power supply providing +15 and -15 volts is required. Table 1 shows the power requirements of each of the interface boards. The external supply should have a current capacity that exceeds the total requirements for all boards for both the +15 and -15 voltages.

A plug in power supply card has been developed for the VIC-20 expansion chassis. Mounting the supply on the expansion chassis requires less work space than a separate supply and reduces the length of the power supply leads. The plug-in supply has a .250 amp capacity for both the +15 and -15 volt supplies.

The power supply and each of the interface boards has a 10 pin connector in the upper left hand corner for external power connections (J-1). The following pin assignments have been established:



TABLE 1  
POWER REQUIREMENTS FOR INTERFACE BOARDS

<u>BOARD</u>	<u>CURRENT REQUIREMENT (AMPS)</u>		
	<u>+5 VOLTS</u>	<u>+15 VOLTS</u>	<u>-15 VOLTS</u>
Analog to Digital	.160	.010	.020
Digital to Analog	.100	.020	.030
Counter/Dio	.100	.012	.012
Strain Gage Conditioner	.000	****	****
Current Driver	.100 Max.	NA	NA

\*\*\*\*Supply Requirements Depend on Excitation Voltage and Strain  
Gage Bridge Resistance.

Pin 1	No Connection
Pin 2	+15 Volts
Pin 3	-15 Volts
Pin 4	Power Supply Common
Pins 5-10	No Connection

A ribbon type cable with multiple connectors is recommended for connecting more than one board to the power supply.

## 2.5 INTERFACE BOARDS

The interface boards can be divided into two categories, those using an address slot and those that do not. The following sections describe each of the interface boards in detail. Some examples of board operation are included in the following sections and additional examples are contained in Section 3.

### 2.5.1 Boards Requiring Address Slots

The following boards each require one address slot:

1. Analog to Digital Converter,
2. Digital to Analog Converter, and
3. Counter and Digital Input/Output

There are eight address slots set aside for boards which require them. The base address of the board is selected by closing one of the switches in SW-1. Only one of the switch contacts should be closed at a time. Table 2 shows the possible board base addresses and the appropriate switch contacts.

Each of the interface boards requiring an address slot is interfaced to the VIC-20 through a versatile interface adaptor (VIA) on the interface card. The VIA provides temporary storage for data, the counter and dio port for the counter/dio board, and other functions. It can be seen from Table 2 that each board occupies 16 addresses. These addresses correspond to registers in the VIA. The function of the registers is shown for each board in Table 3.

The actual address of a register is the sum of the board base address and the register number. For example:

It is necessary to read the low byte of the A/D converter set up as board number four. We will assume that the A/D converter has completed a conversion. The low byte data is in register number one. The board base address is 38960. The address of the low byte data is then  $38960 + 1 = 38961$  decimal or 9831 hex. Peek (38961) in basic or LDA \$9831 in assembler will retrieve the low byte data.

TABLE 2  
SWITCH SETTINGS AND BOARD BASE ADDRESSES

CLOSED CONTACT IN SW-1	BASE ADDRESS	
	HEX	DECIMAL
1	9800	38912
2	9810	38928
3	9820	38944
4	9830	38960
5	9840	38976
6	9850	38992
7	9860	39008
8	9870	39024

TABLE 3  
REGISTER FUNCTIONS FOR THE INTERFACE BOARDS

<u>REGISTER</u>	<u>A/D</u>	<u>D/A</u>	<u>COUNTER/DIO</u>
0	High Byte Data	High Byte Data	Not Used
1	Low Byte Data	Low Byte Data	Digital I/O Port
2	Set to 0	Set to 255	Set to 0
*DETERMINES DIGITAL DATA DIRECTION FOR REGISTER 0*			
3	Set to 0	Set to 255	See Section 2.5.3
*DETERMINES DIGITAL DATA DIRECTION FOR REGISTER 1*			
4-7	Not Used	Not Used	Not Used
8	Not Used	Not Used	Counter Low Byte
9	Not Used	Not Used	Counter High Byte
10	Not Used	Not Used	Not Used
11	Not Used	Not Used	Set to 32 to Count Down
12-15	Not Used	Not Used	Not Used

#### 2.5.1.1 Analog to Digital Converter Board

The A/D board provides one channel of 12 bit resolution single ended analog to digital conversion at a maximum rate of 40 KHZ. The following steps should be performed to set up an A/D board for use with the system.

1. Determine the voltage range required and strap connector P-2 according to Table 4.
2. Connect the signal input according to Table 4.
3. Select the board number by turning on the appropriate switch in SW-1 (closed contacts are considered on).
4. Insert the board either directly into the VIC or into the expansion chassis.
5. Connect the  $\pm 15$  volt power supply to connector J-1.

For each voltage range, the input voltage can be calculated from the A/D converter output by the following formula:

$$\text{Input Voltage} = \frac{\text{Voltage Range}}{4095} \times \text{A/D Converter Output} + \text{Minimum Voltage}$$

For example:

Voltage Range = 20

Minimum Voltage = -10

TABLE 4

## VOLTAGE RANGE SELECTION AND INPUT CONNECTIONS FOR THE A/D BOARD

<u>VOLTAGE RANGE</u>	<u>MINIMUM VOLTAGE</u>	<u>OUTPUT TYPE</u>	<u>CONNECTIONS</u>
20	-10	Complementary Offset Binary	Pin 2 to Pin 4 Input to Pin J2-2 Common Pin J2-1
10	-5	Complementary Offset Binary	Pin 2 to Pin 4 Input to Pin J2-3 Common Pin J2-1
5	-2.5	Complementary Offset Binary	Pin 2 to Pin 4 Pin 4 to Pin 1 Input to Pin J2-3 Common Pin J2-1
5	0	Complementary Binary	Pin 2 to Pin 5 Pin 4 to Pin 1 Input to Pin J2-3 Common Pin J2-1
10	0	Complementary Binary	Pin 2 to Pin 5 Input to Pin J2-3 Common Pin J2-1

A/D Converter Output = 1111000101001110 Complementary Binary  
= 0000111010110001 Binary  
=  $2048+1024+512+128+32+16+1 = 3761$  Decimal

Input Voltage =  $20/4095 \times 3761 + (-10)$   
= 8.369 Volts

The resolution of the converter is calculated from the following formula:

Resolution = Voltage Range/4095

For the case above:

Resolution = Voltage Range/4095  
=  $20/4095$   
= .0049 Volts  
= 4.9 Millivolts

The data registers zero and one (see Table 3) should be set as inputs by setting registers two and three to zero. The A/D converter is then triggered by writing to register zero. Since register zero is set as an input, writing to it has no effect on the data and the write pulse is used to trigger the A/D. The converter has a maximum conversion time of 25 microseconds and software should be designed with enough time between triggering the A/D and reading a sample to allow the converter to complete a conversion.



It is impossible in BASIC to poke register 0 and read the data in less than about 40 milliseconds and therefore, BASIC routines will never overrun the A/D speed. Machine code, however, can be written which will attempt to read the A/D data before the A/D conversion is complete. Null instructions or timing loops should be added if this occurs. Machine code instruction times are given in the programmers reference guide.

The upper four bits of the high data byte are permanently set to one by the hardware on the board. The output of the A/D converter is complementary so that when the complementary data is converted to straight binary the upper four bits become zeros and thus do not affect the magnitude of the upper byte. In this way, a twelve bit A/D sample can be read in as an eight bit low byte and a four bit high byte with the four most significant bits of the high byte set to zero. For an example of A/D operation, see Figure 2.

The A/D board provides gain and offset trim for calibration purposes. The following procedure should be used to calibrate the A/D board:

1. Apply the minimum voltage for the range chosen to the A/D board inputs.
2. Adjust resistor R2 to obtain zero digital output from the board.
3. Apply the maximum voltage for the range chosen.
4. Adjust resistor R4 to obtain the digital code 111111111111 from the board.

```

5 REM*****
6 REM      H/D BOARD TEST
7 REM      BY:  GEORGE A. HARTMAN
8 REM      10/15/83
9 REM*****
10 REM      SET 6522 PORTS AS INPUTS
11 REM
12 REM
13 POKE 38914.0:POKE 38915.0
20 REM
21 REM      CLEAR SCREEN
22 REM
25 PRINT "3"
26 REM
27 REM      TRIGGER AND READ A/D.  WRITING TO THE 6522 PORT WHEN IT IS SET AS AN
28 REM      INPUT DOES NOTHING TO THE DATA ON THE OUTPUT PINS OF THE A/D IT DOES
29 REM      HOWEVER TRIGGER THE A/D.  THE A/D OUTPUT IS COMPLEMENTARY SO CORRECT BY
30 REM      SUBTRACTING FROM 256
31 REM
32 POKE 38912.0
35 C=255-PEEK(38912)+(255-PEEK(38912))*256:PRINT "8"10:"11"100 TO 32
6:ADY.

```

Figure 2. A/D Board Test Routine.

5. Repeat Steps 1 through 4 until no further adjustments are necessary.

#### 2.5.1.2 Digital to Analog Converter Board

The D/A board provides one channel of 12 bit resolution digital to analog conversion at a maximum rate of 200 KHZ. The following steps should be performed to set up a D/A board for use with the system:

1. Determine the voltage range required and strap connector P-2 according to Table 5.
2. Insert the board either directly into the VIC or into the expansion chassis.
3. Select the board number by turning on the appropriate switch in SW-1 (closed contacts are considered on).
4. Connect the external power supply to connector J-1.
5. Connect the output signal according to Table 5.

For each range, the output voltage output can be calculated from the following formula:

$$\text{Output Voltage} = \frac{\text{Voltage Range}}{4095} \times \text{D/A Converter Binary Input} + \text{Minimum Volt}$$

TABLE 5

## VOLTAGE RANGE SELECTION AND OUTPUT CONNECTIONS FOR THE D/A BOARD

<u>VOLTAGE RANGE</u>	<u>MINIMUM VOLTAGE</u>	<u>OUTPUT TYPE</u>	<u>CONNECTIONS</u>
20	-10	Complementary Offset Binary	Pin 5 to Pin 2 Pin 4 to Pin 1 Output to J2-2 Common Pin J2-1
10	-5	Complementary Offset Binary	Pin 5 to Pin 3 Pin 4 to Pin 1 Output to J2-2 Common Pin J2-1
5	-2.5	Complementary Offset Binary	Pin 5 to Pin 3 Pin 4 to Pin 1 Pin 2 to Pin 1 Output to J2-2 Common Pin J2-1
10	0	Complementary Binary	Pin 5 to Pin 3 Output to J2-2 Common Pin J2-1
5	0	Complementary Binary	Pin 5 to Pin 3 Pin 2 to Pin 1 Output to J2-2 Common Pin J2-1

For example:

Voltage Range = 20

Minimum Voltage = -10

D/A Converter Input = 1111111010110001 Complementary Binary

= 0000000101001110 Binary

=  $2048+1024+512+128+32+16+1 = 3761$  Decimal

Output Voltage =  $20/4095 \times 3761 + (-10)$

= 8.369 Volts

The resolution of the converter is calculated from the following formula:

Resolution = Voltage Range/4095

For the case above:

Resolution = Voltage Range/4095

=  $20/4095$

= .0049 Volts

= 4.9 Millivolts

Data registers zero and one (see Table 3) should be set as outputs by setting registers two and three to 255. The output voltage is changed by writing the appropriate digital code to registers zero and one. The converter has a maximum conversion time of five microseconds.

Note that it is impossible to change both registers zero and one at exactly the same time. The D/A output will begin to change as soon as the new code is present at either register zero or one. Machine code software can be written to reduce the time between the two byte transfers to about 10 microseconds. The minimum transfer gap in BASIC is about 20 milliseconds.

As with the A/D converter board the upper four bits of the high data byte are irrelevant since only twelve bits are significant. Writing a number larger than binary 1111 (15 decimal) to register zero will produce the same result as writing any other number with the same lower four bits. The upper four bits are ignored. For example, writing 16 to register zero will cause an output equal to writing 1 to register zero. See Figure 3 for an example of D/A operation.

#### 2.5.1.3 Counter and Digital Input/Output Board

The counter/DIO board provides a sixteen bit counter with selectable divide by 10, 100, or 1,000 and eight bits of TTL level input or output.

##### 2.5.1.3.1 Counter

The counter can be operated in two modes. TTL level pulses can be counted directly or sinusoidal or other periodic functions can be counted using the signal conditioners on the board.

```

*****
1 REM *****
2 REM D/A BOARD TEST
3 REM BY: GEORGE A. HARTMAN
4 REM 10/16/77
5 REM PRODUCES ABOUT A 1/2 HZ SINE WAVE OF FULL AMPLITUDE ON THE P.A.
6 REM *****
7 REM
8 REM
9 REM *****
10 REM
11 REM SET 6822 PORTS AS OUTPUTS
12 REM
13 POKE 38914,255:POKE 38915,255
14 REM
15 REM CLEAR SCREEN
16 REM
17 PRINT "C"
18 REM
19 REM
20 REM SET UP THE SINE WAVE TABLES TO SEND TO THE D/A.
21 REM OL% = LOW BYTE OUTPUT OL% = HIGH BYTE OUTPUT
22 REM OL% AND OL% ARE INTEGER VARIABLES SO INT(A/256) IS
23 REM PERFORMED IN LINE 38 AND INT(A-256*HZ(I)) IS PERFORMED IN LINE 39
24 REM
25 REM
26 REM
27 REM
28 REM
29 REM
30 REM
31 REM
32 DIM HZ(100),LZ(100)
33 FOR I=1 TO 100
34 A=SIN(2*PI*I/100)*2047+2048
35 HZ(I)=A/256
36 LZ(I)=A-256*HZ(I)
37 NEXT I
38 REM
39 REM SEND THE HIGH AND LOW BYTES TO THE D/A
40 REM
41 REM
42 REM
43 REM
44 REM
45 FOR I=1 TO 100
46 POKE 38912,HZ(I):POKE 38913,LZ(I)
47 NEXT I
48 REM
49 REM LOOP BACK FOR ANOTHER SINE WAVE
50 REM
51 REM
52 REM
53 GO TO 45
54 REM
55 REM
56 REM
57 REM
58 REM
59 REM
60 REM
61 REM
62 REM
63 REM
64 REM
65 REM
66 REM
67 REM
68 REM
69 REM
70 REM
71 REM
72 REM
73 REM
74 REM
75 REM
76 REM
77 REM
78 REM
79 REM
80 REM
81 REM
82 REM
83 REM
84 REM
85 REM
86 REM
87 REM
88 REM
89 REM
90 REM
91 REM
92 REM
93 REM
94 REM
95 REM
96 REM
97 REM
98 REM
99 REM
100 REM
*****
READY.

```

Figure 3. D/A Board Test Routine.

The mode is selected by pole 1 of switch 2. Pressing the rocker away from the C1 label activates the direct TTL mode. Toward C1 activates the periodic function mode.

The counter is a sixteen bit unit and counts down from a preset count. The preset count is set by writing the desired low byte value into register eight and the desired high byte value to register nine. The counter will decrement the values in these two registers as one sixteen bit number. For example, if we want to keep track of the number of pulses applied to the counter, we would initially load the counter with 65535 and subtract the subsequent readings from 65535 to produce the pulse count. Counter inputs are shown in Table 6.

#### 2.5.1.3.1.1 TTL Pulse Counting

Zero to five volt pulses with rise times of less than about one microsec can be counted. Divide by ten functions do not operate in this mode. Maximum count rate is approximately 500 Kiloherztz.

#### 2.5.1.3.1.2 Periodic Function Counting

Sinusoidal or other periodic functions cannot be counted by the via directly and require conversion to digital pulses first. This is accomplished by adjusting a low pass filter to remove any unwanted high frequency components from the



**TABLE 6**  
**COUNTER CONNECTIONS AND MODE SWITCH SETTINGS**  
**FOR COUNTER/DIO BOARD**

<u>COUNTER MODE</u>	<u>CONNECTIONS</u>	<u>SWITCH 2 - POLE 1 SETTING</u>
TTL Pulse Counting	Input to J2-12	Away From C1 Label
Periodic Waveform Counting	Input to J2-10	Toward C1 Label
Signal Common	J2-11	

signal and adjusting the high pass filter to remove the DC component of the signal and any unwanted low frequency components. Once the noise and DC components of the signal have been removed, a threshold adjustment is made so that the counter is insensitive to signals smaller than the threshold. Finally, the conditioned signal is passed through a Schmitt trigger to provide the fast rise time needed by the VIA. The Schmitt trigger also has hysteresis characteristics which eliminate multiple counts at the threshold by requiring the voltage to exceed the threshold by a few tenths of a volt before the device will rearm for the next count. Specifications for the on board signal conditioning are:

- 0.15 to 150 Hz cutoff high pass filter.
- 15 to 1500 Hz cutoff low pass filter.
- Threshold sensitivity adjustment from 10 millivolts to ten volts.

In many cases, it is desirable to count events where the total count may exceed 65535. The counter board can be set to divide the incoming pulses by factors of ten. Divide by functions are activated using poles two through four of switch 2. Pressing the rockers toward the C2, C3, or C4 labels activates one stage of divide by ten. Away from C2, C3, or C4 deactivates the divide by function for the stage. Divide by one hundred and divide by one thousand are obtained by activating multiple divide by ten stages.

Certain registers in the VIA must be initialized in order to use the counter. Table 3 shows the various registers and their uses. The manufacturers data catalog for the

6522 VIA chip contains additional information on the register functions.

To use the counter, the following steps must be performed:

1. Set register 11 to 32. This initiates the countdown mode of the 6522 versatile interface adaptor.
2. Set register 2 to zero. This sets the counter port as an input.
3. Set the counter low byte (register 8) to the preset count low byte.
4. Set the counter high byte (register 9) to the present count high byte.
5. Apply input signal and read the count from registers 8 and 9.

Figure 4 shows an example using the counter.

#### 2.5.1.3.2 Digital Input/Output

In addition to the counter, eight bits of digital input or output are available. These bits can be individual set as inputs or outputs in any combination. Each output can drive one standard TTL load and each input is one standard TTL load. To set a bit as an input, the corresponding bit in register three must be set to one. For example, if the lower four bits are to be inputs and the upper four bits are to be outputs, set register three to 11110000 binary or  $128+64+32+16 = 240$  decimal. Sending data to bits set as inputs has no effect on the port. Reading data from outputs may yield random results. When reading input from the port, always mask off any bits not of interest using the BASIC or ASSEMBLER "AND" functions. The digital input and output connections are shown in Table 7. Figure 5 shows an example using the digital input/output port.

```

5 REM*****
6 REM COUNTER/TIMER/DIO BUFFER TEST
7 REM BY: GEORGE A. HARTMAN
8 REM 10/11/83
9 REM*****
10 REM SET 6522 PORTS AS INPUTS
11 REM
12 REM
13 POKE 38914,0:POKE 38915,0
16 REM
17 REM SET 6522 TO COUNT PULSES ON PB-6
18 REM
19 POKE 38923,32
20 REM
21 REM CLEAR SCREEN AND INITIALIZE COUNTER TO 65535
22 REM
25 PRINT "3":POKE 38920,255:POKE 38921,255
26 REM
27 REM DISPLAY COUNT DOWN FROM 65535
28 REM
30 C=PEEK(38920)+PEEK(38921)*256:PRINT "4":GOTO 30
READY.

```

Figure 4. Counter Test Routine.

**TABLE 7**  
**DIGITAL INPUT/OUTPUT CONNECTIONS FOR**  
**THE COUNTER/DIO BOARD**

<u>BIT</u>	<u>CONNECTOR J-2 PIN NUMBER</u>
0	8
1	7
2	6
3	5
4	4
5	3
6	2
7	1
Common	11

```

5 REM*****
6 REM COUNTER/TIMER/DIO BOARD TEST
7 REM BY: GEORGE A. HARTMAN
8 REM 10/17/83
9 REM*****
10 REM
11 REM SET DIO PORT BITS 0-3 AS INPUTS, BITS 4-7 AS OUTPUTS
12 REM 11110000 = 240 DECIMAL
13 REM
14 POKE 38915,240
15 REM
16 REM CLEAR SCREEN
17 REM
18 PRINT "J"
19 REM
20 REM OSCILLATE OUTPUTS
21 REM
22 POKE 38913,240:POKE 38913,0
23 REM
24 REM READ AND DISPLAY INPUTS.
25 REM AND THE REGISTER CODE TO SELECT THE APPROPRIATE OUTPUT BIT
26 REM
27 I=PEEK(38913)
28 PRINT "I AND 8)/8)
29 PRINT (I AND 4)/4)
30 PRINT (I AND 2)/2)
31 PRINT I AND 1)
32 GO TO 30
33 REM
34 READY.

```

Figure 5. Digital Input/Output Test Routine.

#### 2.5.1.3.3 Board Setup

The following steps should be performed to set up a counter/DIO board for use with the system.

1. Select the board number by turning on the appropriate switch in SW-1 (closed contacts are considered on).
2. Select type of input using switch SW-2 pole 1.
3. Connect the signals according to Table 6 for the counter or Table 7 for the digital input/output.
4. Insert the board either directly into the VIC or into the expansion chassis.
5. Connect the external power supply to connector J-1.

If periodic function mode is selected for the counter:

6. Select divide by 1, 10, 100, 1,000 using switch SW-2 poles 2-4. Each pole switched on divides by ten. If no poles are selected then the unit will divide by one, if one pole is selected, the unit will divide by ten, etc.
7. Adjust low and high pass filters for desired bandwidth. The low pass filter is adjusted using resistor R4 and the high pass filter is adjusted using resistor R2.
8. Adjust the threshold sensitivity using resistor R7.

### 2.5.2 Boards Not Requiring Address Slots

There are currently two boards that do not require address slots:

1. Strain gage conditioner, and
2. Current driver.

These boards do not interface with the computer but are signal conditioning boards for general application. They were developed in order to eliminate the need for separate analog signal conditioners and to expand the capability of the system.

#### 2.5.2.1 Strain Gage Conditioner

The strain gage conditioner board is intended to provide excitation and amplification for full strain gage bridges and has the following features:

- Continuously variable gain one to ten thousand.
- Switch selectable filtering. Cutoff frequencies are determined by user selected capacitors.
- Continuously variable excitation levels 3.5 to 13.5 volts.

Single and double arm bridges can also be connected provided external completion resistors are added. Input and output connections are labelled on the board.



The following steps should be performed to calibrate the strain gage conditioner board:

1. Select the filter cutoff frequency from the following equation:

$$\text{Cutoff Frequency} = \frac{1}{2 * \pi * R3 * C}$$

R3 is ten thousand ohms and the filter capacitors should be selected to give a range of cutoff frequencies suitable to the application. Table 8 lists the suggested values and the corresponding filter characteristic.

2. Short the amplifier inputs (IN1 and IN2) to common. Adjust the amplifier offset trimpot to obtain 0.000 volts at the output terminal. Remove the short circuit from the inputs.
3. Adjust the excitation trimpot to obtain the desired excitation voltage at the EX+ terminal. The maximum allowable current drain is approximately 0.075 amps.
4. Select the coarse gain from the ten pole gain select switch according to Table 9. Select a gain slightly lower than the expected final gain. The coarse gain is the sum of the gains from all closed switches. The gain trimpot will be used to perform the final amplifier calibration in Step 6.
5. Connect the bridge and adjust the bridge balance to obtain zero volts at the output terminal with the bridge in the null position.

TABLE 8

FILTER CAPACITORS AND FILTER CUTOFF FREQUENCIES FOR  
THE STRAIN GAGE CONDITIONER

<u>CUTOFF FREQUENCY</u>	<u>CAPACITOR</u>	<u>CAPACITOR VALUE</u>	<u>SWITCH POLE</u>
1.6 Hertz	C7	10.0 uF	1
16. Hertz	C6	1.0 uF	2
160 Hertz	C5	0.1 uF	3
1600 Hertz	C4	0.01 uf	4
Wideband	--	-----	All Open

TABLE 9  
COARSE GAIN SWITCH VALUES FOR THE STRAIN GAGE  
CONDITIONER BOARD

<u>SWITCH POLE</u>	<u>GAIN</u>
None	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
8	256
9	256
10	512

6. Apply full scale to the bridge and adjust the gain trimpot to obtain full scale output from the bridge conditioner board. Full scale output should not exceed 12 volts. The gain trimpot has a range of approximately one to ten times the coarse gain from the gain switch.
7. Repeat Steps 5 and 6 until no further adjustments are necessary.

#### 2.5.2.2 Current Driver

The current driver board provides an interface between the D/A card and controllers or other devices requiring more than two milliamps of current to function properly. Typical laboratory controllers require zero to twelve, four to twenty, or zero to ten milliamps input current.

The following steps should be performed to interface the current driver board to external devices. The input and output terminals are labelled on the board.

1. Select the current limiting resistor from the following equation:

$$\text{Current Limiting Resistor} = 250 - \text{Load Resistance}$$

2. Install the current limiting resistor as R1.

3. Connect the inputs and outputs as labelled on the board. Note that the high output is tied directly to the five volt supply. Use care not to short this lead to common.
4. Short the board inputs and adjust the offset resistor to obtain the desired minimum output current.
5. Apply five volts to the input and adjust the gain resistor to obtain the maximum desired output current ( $< .075$  amps).
6. Repeat Steps 4 and 5 until no further adjustments are necessary.

### SECTION 3

#### APPLICATIONS

The system described in Section 2 has been applied to two laboratory control problems:

- Schenck resonant fatigue testing machine control, and
- Automated furnace control.

The electropneumatic shaker application is still in the development stage and will not be described in further detail here.

The Schenck controller was the original application, however, the furnace controller will be discussed first since it is the simpler of the two.

#### 3.1 AUTOMATED FURNACE CONTROLLER

One of the problems associated with long term heat treating of materials or curing procedures is that constant operator supervision is necessary if complicated temperature profiles are required. The VIC-20 system provides a means to preprogram the required profile and allow the computer to control the heat treating operation. Figure 6 shows the software that is currently being used to control a heat treating furnace in the MLLN laboratory.

```

100 REM***** FURNACE CONTROL PROGRAM *****
101 REM
102 REM      GEORGE A. HARTMAN      7/23/1983
103 REM      USES A VIC-20 D/A BOARD SET AS BOARD #1 WITH 0-5 VOLT OUTPUT
105 REM*****
106 REM
110 PRINT "FURNACE CONTROL PROGRAM"
134 REM
135 REM      SET D/A PORTS AS OUTPUTS
136 REM
140 POKE38914,255:POKE38915,255
141 REM
142 REM      SET OUTPUT TO ZERO
143 REM
145 POKE38912,255:POKE38913,255
146 REM
147 REM      DIMENSION FOR 50 BLOCKS MAX
148 REM
150 DIM S(50),T(50)
200 REM*****
201 REM      GET BLOCK DATA
202 REM*****
206 REM
207 REM      PRINT HEADER
208 REM
210 GOSUB3005
212 REM
213 REM      INITIALIZE THE ZERO BLOCK AND SET UP N FOR TOTAL BLOCKS
214 REM
218 PRINT " 0      75      0"
219 N=0
220 S(0)=75

```

Figure 6. Furnace Control Program.

```

221 T(0)=0
222 DAYS=0
224 REM
225 REM CHANNEL 1 IS THE KEYBOARD. USING GET# DOESN'T PRINT THE ?
226 REM
228 OPEN1.0
230 REM
231 REM TAKE BLOCK DATA UNTIL THE OPERATOR ENTERS AN R
232 REM
233 INPUT#1,R$
234 IFA$="R" THEN 260
235 GOSUB1010
237 PRINT
238 GO TO 233
255 REM
256 REM PRINT SCREEN TITLES
257 REM
260 GOSUB2005
270 REM
271 REM INITIALIZE BLOCK NUMBER AND TIME FUNCTION
272 REM
280 I=0
285 TI$="000000"
290 TZ=TI
300 REM*****
301 REM MAIN LOOP GENERATES OUTPUT SIGNAL
302 REM*****
305 I=I+1
306 REM
307 REM SET START TIME FOR THIS BLOCK
308 REM

```

Figure 6 (Continued). Furnace Control Program.



```

309 T0=TZ
310 REM
311 REM      CHECK FOR LAST BLOCK
312 REM
313 IF I>N THEN 510
314 REM
315 REM      CALCULATE RATE OF TEMPERATURE CHANGE AND PRINT IT
316 REM
319 RATE=(S(I)-S(I-1))/T(I)
320 GOSUB 5000
339 REM
340 REM      C=D/A UNITS PER DEGREE FAHRENHEIT
345 REM      ERR=BARBER-COLEMAN CONTROLLER ERROR IN DEGREES F
350 REM      D=OFFSET FOR 1 VOLT. RANGE OF CONTROLLER IS 1 TO 5 VOLTS
352 REM
355 C=4096/2500
360 ERR=0
365 D=500
400 REM*****
401 REM      CALCULATE OUTPUT <LINEAR INTERPOLATION BETWEEN SETPOINTS>
402 REM*****
409 REM
410 REM      OUT=SETPOINT IN DEGREES FAHRENHEIT
411 REM      OH%=HIGH BYTE OUTPUT
412 REM      OL%=LOW BYTE OUTPUT
413 REM
420 TX=TI
421 REM
422 REM      CHECK FOR NEW DAY
423 REM
425 IF TZ-DAYS>TX THEN DAYS=DAYS+86400#60
426 TZ=TX+DAYS

```

Figure 6 (Continued). Furnace Control Program.

```

427 OUT=S(I-1)+RATE*(TZ-T0)/60+D+ERR
428 OHZ=C#OUT/256
430 OLZ=C#OUT-256*OHZ
431 REM
432 REM SEND OUTPUT TO D/A
433 REM
434 POKE38912,255-OHZ
435 POKE38913,255-OLZ
436 REM
437 REM PRINT CURRENT TIME
438 REM
439 H$=STR$(INT(TZ/3600/60)):IFVAL(H$)>9THENH$=RIGHT$(H$,2)
440 M$=MID$(TI$,3,2):S$=RIGHT$(TI$,2)
441 PRINT"#####";H$;" ";M$;" ";S$;TAB(12);
442 REM
443 REM PRINT CURRENT SETPOINT IN OPERATOR UNITS
444 REM
445 PRINTINT(OUT-D-ERR);" "
446 REM
447 REM PRINT TIME LEFT IN THIS BLOCK
448 REM
449 PRINT"#####";INT((T(I)*60-TZ+T0)/360)/10+.1;" "
451 REM
452 REM IF THIS BLOCK IS OVER THEN GET THE NEXT ONE
453 REM
454 IF(TZ-T0)>T(I)*60THEN305
455 REM
456 IF MENU IS REQUESTED THEN PRINT IT
457 REM
458 GETA$
459 IF A$=CHR$(133)THENGOSUB4007
460 GOTO420
461 REM#####
462 REM STOP PROGRAM

```

Figure 6 (Continued). Furnace Control Program.

```

502 REM*****
504 REM
505 REM      SHUT OFF D/A
506 REM
510 POKE38912,255:POKE38913,255
515 PRINT":PROGRAM ENDED"
520 END
1000 REM*****
1001 REM      STRIP OFF BLOCK NUMBER, SETPOINT, AND TIME FROM STRING
1002 REM*****
1010 I=VAL(MID$(A$,1,2))
1012 REM
1013 REM      KEEP TRACK OF BIGGEST BLOCK NUMBER
1014 REM
1015 IF I>NTHENN=I
1020 S(I)=VAL(MID$(A$,3,10))
1030 T(I)=VAL(MID$(A$,13,10))*60
1040 RETURN
2000 REM*****
2001 REM      PRINT HEADER
2002 REM*****
2005 PRINT":ELAPSED      SETPOINT      TIME      DEGREES      HH:MM:SS      FAHRENHEIT"
2010 PRINT"*****      *****      *****      *****      *****"
2020 PRINT"*****BLOCK      RATE      NO.      DEG/MIN      *****"
2030 PRINT"*****TIME LEFT *****"
2040 PRINT"*****"
2045 PRINT"*****PRESS F1 FOR PROFILE";
2050 RETURN
3000 REM*****
3001 REM      PRINT DATA INPUT HEADER
3002 REM*****

```

Figure 6 (Continued). Furnace Control Program.

```

3005 PRINT"ENTER SET POINTS AND THE TIME TO COMPLETE THE TRANSITION"
3010 PRINT"(ENTER R TO RESUME PROGRAM)"
3020 PRINT"END SETPOINT TIME DEGREES F MINUTES ** ***** *****"
3030 RETURN
4000 REM*****
4001 REM REVIEW PROFILE
4002 REM*****
4004 REM
4005 REM CLEAR SCREEN
4006 REM
4007 PRINT"C"
4008 REM
4009 REM PRINT HEADER AND BLOCK DATA
4010 REM
4011 GOSUB3020
4012 FORK=1TON
4014 PRINTK;TAB(5);S(K);TAB(15);T(K)/60
4020 NEXT
4025 REM
4026 REM TIMING LOOP
4027 REM
4030 FORJ=1TO10000:NEXT
4035 REM
4036 REM GO BACK TO NORMAL EXECUTION
4037 REM
4040 GOSUB2005
4045 GOSUB 5000
4050 RETURN
5000 PRINT"*****";1,INT(RATE*600)/10;"||"
5010 RETURN
READY.

```

Figure 6 (Concluded). Furnace Control Program.

The software is designed to allow up to fifty setpoint changes within a single profile. The D/A output is fed into a Barber-Coleman 520 series controller with external one to five volt linear input. The program as listed requires too much memory to run without a memory expansion cartridge. A running version for the VIC-20 with no memory expansion is generated by removing the remark statements.

The program prompts the operator for the block number, the time for the block, and temperature at the end of the block. The operator may change parameters for any block at any time during the data entry segment of the program. The profile may be reviewed at any time during the heat treatment by pressing the user defined key F1.

A planned improvement in the system will be to install an A/D board to read the actual temperature and include a closed loop control section similar to the one in the Schenck controller described in the next section. This would eliminate the need for the Barber-Coleman controller and digital pyrometer display that are now required.

### 3.2 SCHENCK RESONANT FATIGUE TEST MACHINE CONTROLLER

The original application of the VIC system was to control four of the Schenck fatigue machines in the MLLN laboratory. The machine controls were not operating and refit was estimated to cost ten thousand dollars each.

The VIC controls have been installed on two of the four machines. The remaining two will be converted if demand for their use increases.

### 3.2.1 Schenck Characteristics

The Schenck testing machines are based on the resonance principle. The machine base acts as a large reaction mass to which one end of the specimen is attached. The other end of the specimen is attached to one end of a spring. The other end of the spring is attached to a mass mounted eccentrically on a shaft. The shaft is rotated by an electric motor which sets up a vibration of the spring. The speed of the motor controls the frequency of vibration and the spring stiffness and eccentric mass are designed to have a natural frequency of about 50 Hz. As the motor speed approaches the natural frequency, the magnitude of the load transmitted through the specimen to the frame of the machine increases in a highly nonlinear fashion. This means that a small change in the motor speed yields a large change in the specimen load.

### 3.2.2 VIC Controller

The VIC A/D is interfaced to the Schenck via a strain gage conditioner board which provides an output signal proportional to the specimen load. The D/A board drives the motor through a commercial DC motor controller. The cycle count is obtained by driving the counter board with the sinusoidal load waveform.

The software used to control the Schenck is shown in Figure 7. The program as listed is too large to run without a memory expansion card for the unexpanded VIC-20. A version which will run without memory expansion can be generated by removing the remark lines from the program.

The routine requires that the A/D board be set as board one, the D/A board be set as board two, and the counter board be set as board three. As with the furnace controller program, the Schenck program prompts the operator for all required input data.

Much of the program is formatting which makes the operator interface easier. Although this is not necessary, it makes it possible for inexperienced operators to use the controller without having to decipher unclear controls.

The routine at line 600 sets up the machine language subroutine which reads the A/D 2550 times and calculates the maximum and minimum load in about .2 seconds. The subroutine was written in ASSEMBLY language and is shown in Figure 8. The ASSEMBLY language program was converted to a series of decimal numbers which are contained in the data statements in lines 640-690. In the way the BASIC program is self-contained and the operator simply loads the routine from tape or disk and when it is run, it sets up the machine language routine by itself. Line 610 changes the top of memory so that the BASIC interpreter will not destroy the machine code.

```

1 REM*****
2 REM, SCHENCK CONTROL PROGRAM BY: GEORGE A. HARTMAN 10/12/83
3 REM, BOARDS: A/D ... #1 D/A ... #2 COUNTER/TIMER/DIO ... #3
4 REM*****
5 REM
6 REM SET UP MACHINE LANGUAGE ROUTINE.
7 REM
8 GOSUB 610
9 REM
10 REM SET A/D PORTS AS INPUTS AND D/A PORTS AS OUTPUTS AND TURN D/A OFF
11 REM
12 POKE 38914,0:POKE 38915,0
13 POKE 38930,255:POKE 38931,255
14 POKE 38928,255:POKE 38929,255
15 REM
16 REM GET SYSTEM OF UNITS
17 REM
18 GOSUB 406
19 REM
20 REM
21 REM P3=FULL SCALE A/D (POUNDS)
22 REM P4=COMMAND AMPLITUDE (POUNDS)
23 REM P5=COMMAND AMPLITUDE (A/D UNITS)
24 REM P6=POUNDS/A/D UNIT
25 REM
26 P3=4000
27 REM GET DESIRED LOAD
28 REM
29 GOSUB 505
30 P4=P2-P1
32 P6=P3/2048
34 P5=INT(P4/P6)

```

Figure 7a. Schenck Control Program.



```

35 REM
36 REM SET MEAN LOAD
37 REM
38 GOSUB310
39 REM
40 REM GET MAXIMUM CYCLES TO RUN
41 REM
42 GOSUB705
43 REM
44 REM START TEST
45 REM
46 PRINT"TPUSH RESET SWITCH TO START AND RELEASE IT. PRESS RETURN TO START TEST
"
47 INPUT$
48 REM
49 REM PRINT SCREEN LABELS SO WE DON'T HAVE TO DO IT IN THE CONTROL LOOP
50 REM
52 PRINT"J";TAB(8);B$;" MAX"
54 PRINT:PRINTTAB(8);B$;" MIN"
60 PRINT:PRINTTAB(11);"CYCLES"
65 PRINT:PRINTTAB(11);"OUTPUT %"
70 PRINT"XXXXXXXXXXXXPRESS F1 TO STOP TEST"
100 REM*****
101 REM MAIN CONTROL LOOP
102 REM*****
103 REM Z=INTEGRAND
104 REM G=GAIN
105 REM R=RESET VALUE
106 REM
107 Z=2400:G=.015:R=2.6/SQR(P4)
108 REM
109 REM Y=ERROR

```

Figure 7a (Continued). Schenck Control Program.

```

110 REM      01,02=D/A OUTPUT BYTES
111 REM      SYS7536 CALLS A/D SUBROUTINE
112 REM      ON RETURN TO BASIC MAX IS STORED AT 7678,7679 MIN AT 7676,7677
122 REM      AVERAGE 5 READINGS
123 REM
125 H=0:L=0
126 FORK=1T05
127 SYS7536
130 H=H+PEEK(7679)*256+PEEK(7678)
132 L=L+PEEK(7677)*256+PEEK(7676)
133 NEXT
135 H=H/5
136 L=L/5
138 Y=P5-H+L
140 Z=Y*R+Z
150 O=Y*G+Z
156 IF O>4095 THEN O=4095
158 IF O<0 THEN O=0
160 REM
161 REM      COUNTER IS COUNTING DOWN FROM 65535 SO COUNT=65535-READING
163 REM
164 C=65535-PEEK(38953)*256-PEEK(38952)
165 REM
166 REM      CHECK ERROR AT 2000 CYCLES AND CHECK IF MAXIMUM COUNT IS EXCEEDED
167 REM
168 IF C<2 THEN 170
169 IF Y>100 THEN 205
170 IF C>=TC/1000 THEN 205
171 REM
172 REM      CALCULATE OUTPUT AND SEND TO D/A
173 REM
175 O1=INT(O/256)

```

Figure 7a (Continued). Schenck Control Program.

```

176 02=INT(0-256#01)
177 POKE38928,15-01
178 POKE38929,255-02
180 REM
181 REM CHECK IF THE OPERATOR WANTS TO STOP THE TEST
183 REM
184 GETA$
186 IFA$=CHR$(133)THEN205
187 REM
188 REM PRINT CURRENT STATUS
189 REM
190 PRINT "H";INT(B*(H-2047)*P6/10)*10;"H"
192 PRINT:PRINTINT(B*(L-2047)*P6/10)*10;"H"
193 PRINT:PRINTC#1000
194 PRINT:PRINTINT(O/4095*10000)/100;"H"
199 GOTO125
200 REM*****
201 REM PROGRAM END
202 REM*****
203 REM SHUT OFF D/A
204 REM
205 POKE38928,255:POKE38929,255
207 REM
208 REM PRINT FINAL CYCLE COUNT
209 REM
210 PRINT"CYCLE COUNT=";C#1000
211 REM
212 REM PROMPT OPERATOR FOR RESTART
213 REM
215 PRINT"MCHECK FOR BROKEN SAMPLE"
216 PRINT"DO YOU WANT TO RESTART(Y/N)"
218 INPUTA$

```

Figure 7a (Continued). Schenck Control Program.

```

219 IF A$="Y" THEN 18
220 REM
222 REM PROMPT OPERATOR TO SHUT OFF MACHINE
224 REM
230 PRINT "SET RESET SWITCH TO OFF THEN PRESS RETURN"
235 INPUT A$
240 REM
242 REM DISPLAY END MESSAGE AND STOP PROGRAM
244 REM
250 PRINT "*****PROGRAM ENDED*****"
255 END
300 REM *****
301 REM MANUAL ADJUST MEAN LOAD AND DISPLAY MEAN LOAD
302 REM *****
303 REM
304 REM DISPLAY INSTRUCTIONS
305 REM
310 PRINT "ADJUST BALANCE WITH NOSAMPLE. INSTALL SPECIMEN AND ADJUST MEAN LOAD."
315 PRINT "SET PRELOAD SWITCH TO OFF AND PRESS F3 WHEN DONE"
317 REM
318 REM DISPLAY DESIRED MEAN LOAD CALCULATED FROM MAX AND MIN INPUTS
319 REM
320 PRINT "PRINT:PRINT((P1+P4/2)*B+.5);TAB(7);B$;" DESIRED"
322 REM
323 REM DISPLAY TITLE SO WE DON'T HAVE TO DO IT IN THE LOOP
324 REM
330 PRINT "PRINTTAB(7);B$;" ACTUAL"
335 REM
336 REM AVERAGE 10 READINGS AND FIX RESOLUTION TO 10 POUNDS
337 REM
340 H=0

```

Figure 7a (Continued). Schenck Control Program.

```

342 FORK=1T010
343 REM
344 REM TRIGGER A/D
345 REM
346 POKE38912.0
347 REM
348 REM GET ANSWER FROM A/D, CALCULATE LOAD, AND SUM UP RESULTS
349 REM
350 H=H+P6*B*(-2047+(255-PEEK(38912))*256+255-PEEK(38913))
355 NEXTK
356 REM
357 REM RECOVER AVERAGE
358 REM
359 H=INT(H/100)*10
360 REM
361 REM PRINT RESULT
362 REM
363 PRINT "J":H;" "
364 REM
365 REM CHECK IF OPERATOR HAS PRESSED F3 KEY
366 REM
370 GETA$
373 IFA$=CHR$(134)THENRETURN
375 REM
376 REM GO BACK FOR ANOTHER READING
377 REM
380 GOTO340
400 REM*****
402 REM GET SYSTEM OF UNITS
404 REM*****
406 PRINT "ARE YOU USING:":PRINT " POUNDS (P)":PRINT " NEWTONS (N)":
408 INPUT B$
410 IFB$="P" THENB=1:B$="POUNDS":RETURN
420 B=4.448:B$="NEWTONS"
430 RETURN
500 REM*****
501 REM GET MAX AND MIN LOAD FROM OPERATOR

```

Figure 7a (Continued). Schenck Control Program.

```

502 REM*****
505 PRINT"ENTER MAXIMUM LOAD FORTHIS TEST IN ";B$
507 INPUTP2
508 P2=P2/B
510 REM
511 REM CHECK IF LARGER THAN MACHINE CAPACITY
512 REM
515 IFABS(P2)>P3THENPRINT"OUT OF RANGE - TRY AGAIN":GOTO505
520 PRINT"ENTER MINIMUM LOAD FORTHIS TEST IN ";B$
522 INPUTP1:P1=P1/B
524 P1=P1/B
525 REM
526 REM CHECK IF:
527 REM PAST MACHINE CAPACITY
528 REM LOAD RANGE PAST MACHINE CAPACITY
529 REM LOAD RANGE TOO SMALL FOR MACHINE TO CONTROL
530 REM MEAN LOAD PAST MACHINE CAPACITY
531 REM
535 IFP1<-P3ORP1>P2ORP2-P1>P3ORP2-P1<4000R(P2+P1)/2>P3/2THENPRINT"OUT OF RANGE":
GOTO520
540 RETURN
600 REM*****
601 REM SET MACHINE CODE BY POKING IN DECIMAL EQUIVALENTS OF ASSEMBLY CODE
602 REM*****
604 REM
606 REM SET BASIC TOP OF MEMORY BELOW MACHINE CODE AREA
608 REM
610 POKE51,111:POKE52,29:POKE55,111:POKE56,29
620 REM
622 REM READ MACHINE CODE FROM DATA STATEMENTS AND POKE INTO MEMORY
624 REM
630 FORI=7536TO7664

```

Figure 7a (Continued). Schenck Control Program.

```

632 READC
634 POKEI,C
636 NEXT
640 DATA141,0,152,169,10,141,249,29,169,255,141,252,29,141,253,29,169,0,141,254,
29,141
650 DATA255,29,162,255,173,1,152,73,255,141,250,29,173,0,152,73,255,141,251,29,1
41,0,152
660 DATA205,255,29,240,14,144,26,141,255,29,173,250,29,141,254,29,76,190,29,173,
250,29
670 DATA205,254,29,144,6,173,251,29,76,164,29,173,251,29,205,253,29,240,14,176,2
6,141
680 DATA253,29,173,250,29,141,252,29,76,226,29,173,250,29,205,252,29,176,6,173,2
51,29,76
690 DATA200,29,202,240,3,76,138,29,206,249,29,240,3,76,136,29,96
699 RETURN
700 REM*****
701 REM GET MAXIMUM NUMBER OF CYCLES TO RUN AND SET UP COUNTER
702 REM*****
705 PRINT"ENTER CYCLES TO RUN (30 MILLION MAX)":INPUTC
709 REM
710 REM SET COUNTER PORT AS INPUT AND SET COUNTER MODE REGISTER TO 32
711 REM
720 POKE38946,0
721 POKE38955,32
722 REM
723 REM SET INITIAL COUNT TO 65535
724 REM
725 POKE38952,255:POKE38953,255
730 RETURN

READY.

```

Figure 7a (Concluded). Schenck Control Program.

A,A1 .....	D/A ENABLE ADDRESSES (DATA DIRECTION REGISTERS FOR PORTS A AND B ON VIA #3)
A2,A3 .....	A/D ENABLE ADDRESSES (DATA DIRECTION REGISTERS FOR PORTS A AND B ON VIA #4)
A\$ .....	CHARACTER VARIABLE FOR KEYBOARD RESPONSES
AZ .....	(NUMBER OF CYCLES TO RUN) / 1000
B .....	UNITS CONVERSION FACTOR (1 FOR POUNDS OR 4.448 FOR NEWTONS)
B\$ .....	UNITS STRING ("POUND" OR "NEWTONS")
B% .....	DUMMY VARIABLE
C\$ .....	CARRIAGE RETURN VARIABLE
CZ .....	(CYCLES RUN) / 1000
H .....	MAXIMUM LOAD FROM MACHINE LANGUAGE ROUTINE
I .....	LOOP INDEX
K .....	LOOP INDEX
L .....	MINIMUM LOAD FROM MACHINE LANGUAGE ROUTINE
O .....	CALCULATED D/A OUTPUT VALUE
O1 .....	D/A OUTPUT HIGH BYTE
O2 .....	D/A OUTPUT LOW BYTE
P1 .....	COMMANDED MINIMUM LOAD (POUNDS)
P2 .....	COMMANDED MAXIMUM LOAD (POUNDS)
P3 .....	FULL SCALE (POUNDS)
P4 .....	COMMANDED AMPLITUDE (POUNDS)
P5 .....	COMMANDED AMPLITUDE (A/D UNITS)
P6 .....	POUNDS PER LEAST SIGNIFICANT BIT
R .....	CONTROL LOOP RESET VALUE FOR INTEGRATION
Y .....	CONTROL LOOP ERROR VALUE
Z .....	CONTROL LOOP INTEGRATED ERROR

Figure 7b. Variable Definitions for the Schenck Control Application.



MEMORY	OP CODE	DATA	REMARKS
***** 1D70	STA	DATA **** \$9800	***** TRIGGER A/D
1D73	LDA	\$0A	COUNT DOWN
1D75	STA	\$1DF9	FROM 10 TO 0
1D78	LDA	\$0FF	INITIALIZE MINIMUM
1D7A	STA	\$1DFC	
1D7D	STA	\$1DFD	
1D80	LDA	\$00	INITIALIZE MAXIMUM
1D82	STA	\$1DFE	
1D85	STA	\$1DFF	
1D88	LDX	\$0FF	COUNT DOWN FROM 255
1D8A	LDA	\$9801	GET LOW BYTE, COMPLEMENT
1D8D	EOR	\$0FF	IT AND STORE IT
1D8F	STA	\$1DFA	
1D92	LDA	\$9800	GET HIGH BYTE,
1D95	EOR	\$0FF	COMPLEMENT AND STORE IT
1D97	STA	\$1DFB	
1D9A	STA	\$9800	RETRIGGER A/D

Figure 8. Machine Language Program Listing for the Schenck Control Application.



```

*****
COUNTER ROUTINE
*****
1DE2      DEX
1DE3      BEQ
1DE5      JMP
          ARE WE DONE WITH THIS
          SET OF 255 SAMPLES ?
          $1DE8
          $1D8A
1DE8      DEC
1DEB      BEQ
1DED      JMP
          ARE WE DONE WITH ALL 10
          SETS OF 255 SAMPLES ?
          $1DF9
          $1DF0
          $1D88
1DF0      RTS
          RETURN TO BASIC
          MAX IS STORED AT
          HIGH BYTE ..... $1DFF
          LOW BYTE ..... $1DFE
          MIN IS AT
          HIGH BYTE ..... $1DFD
          LOW BYTE ..... $1DFC

```

Figure 8 (Concluded). Machine Language Program Listing for the Schenck Control Application.

The main closed loop control routine starts at line 125. Note that in line 107, the reset (integral) term "R" for the loop is a function of the load amplitude and is not a constant. This was necessary because of the exponential nature of the load - motor speed relationship.

The error trap in line 169 is not executed unless the cycle count is greater than 2000. This gives the motor time to come up to speed without being shut down due to too large an error signal "Y".

The control loop is executed about five times per second. This is fast enough to control the motor speed and the specimen load on the Schenck machine but may be too slow for other applications. Control loop execution time can be reduced to less than a millisecond by eliminating all basic commands and reprogramming the loop calculations in machine code.

## SECTION 4

### SUMMARY

The VIC system described is an inexpensive and versatile data acquisition and real time control system that is applicable to a range of laboratory problems. The system has been successfully applied to two control problems and additional applications have been identified.

The unit is a modular design which allows it to be reconfigured easily as new applications are identified. The use of the VIC-20 provides the capability to easily program clear displays and input formats which reduce operator errors and the time to learn the system for a given application.

**APPENDIX A**  
**PARTS LISTS FOR THE INTERFACE BOARDS**

PARTS LIST FOR EXPANSION CHASSIS

<u>ITEM</u>	<u>QTY.</u>	<u>DESCRIPTION</u>	<u>MANUFACTURER</u>	<u>MANUFACTURER'S PART NUMBER</u>
J1-J8	8	44 Pin Card Edge Connectors	TRW Cinch	44B-10M-1

# PARTS LIST FOR A/D BOARD

ITEM	QTY.	DESCRIPTION	MANUFACTURER	MANUFACTURER'S PART NUMBER
IC-1	1	1 of 8 Decoder	Signetics	74LS138
IC-2	1	Versatile Interface Adaptor	Synertech	SY6522
IC-3	1	Quad Nor Gate	Motorola	MC14001B
IC-4	1	12 Bit 25 uSec A/D Converter	Analog Devices	AD ADC80-12
C1-C3,C5	3	.1 uF 35 V Nonpolarized Cap.	Centralab	CY20C104M
C4,C6	2	1 uF 35 V Nonpolarized Cap.	Centralab	CY30C105M
R1	1	1.8 Meg 1/4 Watt Resistor	Corning	RLR07C1804GR
R2,R4	2	10 K Trimpots	Bourns	3009P-1-103
R3	1	10 Meg 1/4 Watt Resistor	Corning	RLR07C1005GR
S1,S3	2	IC Socket 14 Pin Dip	Cambion	703-3777-01-04-1
S2	1	IC Socket 40 Pin .1" x .6"	Cambion	703-3766-01-04-1
S4	1	IC Socket 32 Pin .1" x .9"	Aires	32-9513-10
SW-1	1	8 Pole SPST Dip Switch	Grayhill	76NSB08
J1	1	PC Mount Jack	T&B Ansley	609-1002M
J2	1	Terminal Strip	Buchanan	SSB4S4S11
P2	1	Pin Strip	Electrovert	8140 Series



# PARTS LIST FOR D/A BOARD

<u>ITEM</u>	<u>QTY.</u>	<u>DESCRIPTION</u>	<u>MANUFACTURER</u>	<u>MANUFACTURER'S PART NUMBER</u>
IC-1	1	1 of 8 Decoder	Signetics	74LS138.
IC-2	1	Versatile Interface Adaptor	Synertech	SY6522
IC-3	1	12 Bit D/A Converter	National	DAC1280ACD
CL-C4	4	.1 uF 35 V Nonpolarized Cap.	Centralab	CY20C104M
S1	1	IC Socket 14 Pin Dip	Cambion	703-3777-01-04-1
S2	1	IC Socket 40 Pin .1" x .6"	Cambion	703-3766-01-04-1
S3	1	IC Socket 24 Pin .1" x .6"	Cambion	703-3790-01-04-1
S4	1	IC Socket 16 Pin Dip	Cambion	703-3778-01-04-1
SW-1	1	8 Pole SPST Dip Switch	Grayhill	76MSB08
J1	1	PC Mount Jack	T&B Ansley	609-1002M
J2	1	Terminal Strip	Buchanan	SSB4S4S11
P2	1	Pin Strip	Electrovert	8140 Series

# PARTS LIST FOR COUNTER AND DIGITAL INPUT/OUTPUT BOARD

ITEM	QTY.	DESCRIPTION	MANUFACTURER	MANUFACTURER'S PART NUMBER
IC-1	1	1 of 8 Decoder	Signetics	74LS138
IC-2	1	Versatile Interface Adaptor	Synertech	SY6522
IC-3-5	3	Decade Counter	National	CD4017B
IC-6	1	Quad Schmitt Trigger	National	CD4093B
IC-7	1	Quad OP Amp	Texas Instr.	TL084
CI-C3	3	.1 uF 35 V Nonpolarized Cap.	Centralab	CY20C104M
C4	1	1 uF 35 V Nonpolarized Cap.	Centralab	CY30C105M
R1	1	2.2 K 1/4 Watt Resistor	Corning	RLR07C2201GR
R2	1	1 Meg Trimpot	Bourns	3009P-1-105
R3,R5,R6	3	1 K 1/4 Watt Resistor	Corning	RLR07C1001GR
R4,R7	2	100 K Trimpot	Bourns	3009P-1-104
D1	1	5.1 Volt Zener Diode	Motorola	IN751
S1,S6,S7	3	IC Socket 14 Pin Dip	Cambion	703-3777-01-04-1
S2	1	IC Socket 40 Pin .1" x .6"	Cambion	703-3766-01-04-1
S3,S4,S5	3	IC Socket 16 Pin Dip	Cambion	703-3778-01-01-1
SW-1	1	8 Pole SPST Dip Switch	Grayhill	76MSB08
SW-2	1	4PDT Dip Switch	Grayhill	76SC04
J1	1	PC Mount Jack	T&B Ansley	609-1002M
J2	1	Terminal Strip	Buchanan	SSB4S12S11

# PARTS LIST FOR STRAIN GAGE CONDITIONER BOARD

ITEM	QTY.	DESCRIPTION	MANUFACTURER	MANUFACTURER'S PART NUMBER
R1	1	10K Ohm Metal Film Resistor	Corning	RLR07C1002GR
R2	1	100K Ohm Metal Film Resistor	Corning	RLR07C1003GR
R3	1	10K Ohm Metal Film Resistor	Corning	RLR07C1002GR
R4	1	10K Ohm Metal Film Resistor	Corning	RLR07C1002GR
R5	1	10K Ohm Metal Film Resistor	Corning	RLR07C1002GR
R6	1	5 Ohm 1 Watt Carbon Resistor	Allen Bradley	GB56G5
R7	1	10K Ohm Metal Film Resistor	Corning	RLR07C1002GR
Balance	1	10K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-103
Excit.	1	50K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-503
Gain	1	100K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-104
Offset	1	100K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-104
C1	1	100 pF Ceramic Capacitor	Kemet	C052C101G5X5CA
C2	1	0.1 uF Ceramic Capacitor	Kemet	C052C104G5X5CA
C3	1	0.1 uF Ceramic Capacitor	Kemet	C052C104G5X5CA
SW-1	1	10 Pole Dip Switch	Grayhill	76MSB10
SW-2	1	4 Pole Dip Switch	Grayhill	76MSB04
IC1	1	723 Precision Regulator	National	LB723C
IC2	1	AD612BD Precision Instr. Amp.	Analog Devices	AD612BD
IC3	1	ua741 or LF356 OP Amp	National	LM741A or LF356
C4-C7	4	Filter Capacitors	Kemet	User Chooses

# PARTS LIST FOR CURRENT DRIVER BOARD

<u>ITEM</u>	<u>QTY.</u>	<u>DESCRIPTION</u>	<u>MANUFACTURER</u>	<u>MANUFACTURER'S PART NUMBER</u>
R1	1	Current Limiting Resistor	Allen Bradley	User Chooses
TR1	1	2N696 NPN Silicon Transistor	Motorola	2N696
Offset	1	100K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-104
Gain	1	100K Ohm 15 Turn Trim Resistor	Bourns	3009P-1-104

**APPENDIX B**  
**SCHEMATICS FOR THE INTERFACE BOARDS**

**VIC-20**  
**A/D BOARD No. 830801**

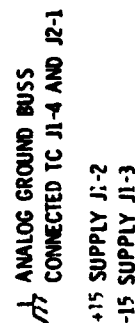
DIGITAL  
GROUND BUSS  
CONNECTED TO P1-Z

BOARD SIZE: 5 x 4 INCHES

P1 - 44 PIN DOUBLE SIDED  
MALE CARD EDGE PLUG  
- COMPONENTS SHALL BE ON  
THE NUMBERED PIN SIDE  
- .156 COND. SPACING  
- SHALL MATE WITH TRW CINCH  
50-44S-30-2 OR EQUIV.

P2 - 0.1 INCH CENTER  
PC WIRE WRAPPINGS

GROUND AND 5 VOLT SUPPLY  
CONDITIONS SHALL BE AT LEAST 1/16 WIDE



J1 - T + B ANSLEY 609-1002M  
MOUNTED OPPOSITE P1  
J2 - BUCHANAN SSB4S4S11

P1-F P1-H P1-J P1-T P1-V P1-W P1-X P1-Y P1-Z P1-AA P1-AB P1-AC P1-AD P1-AE P1-AF P1-AG P1-AH P1-AI P1-AJ P1-AL P1-1 P1-2 P1-3 P1-4 P1-5 P1-6 P1-7 P1-8 P1-9 P1-10 P1-11 P1-12 P1-13 P1-14 P1-15 P1-16 P1-17 P1-18 P1-19 P1-20 P1-21 P1-22 P1-23 P1-24 P1-25

+5V C4  
 SW-1  
 8 POLE DIP +5  
 C3  
 J2-3  
 J1-3  
 -15V  
 J2-1  
 J1-4  
 J2-4  
 J1-1  
 J2-2  
 0-10V OUT  
 GROUND  
 P2

IC1 74LS138  
 IC2 SY6522  
 IC3 DAC1280ADC

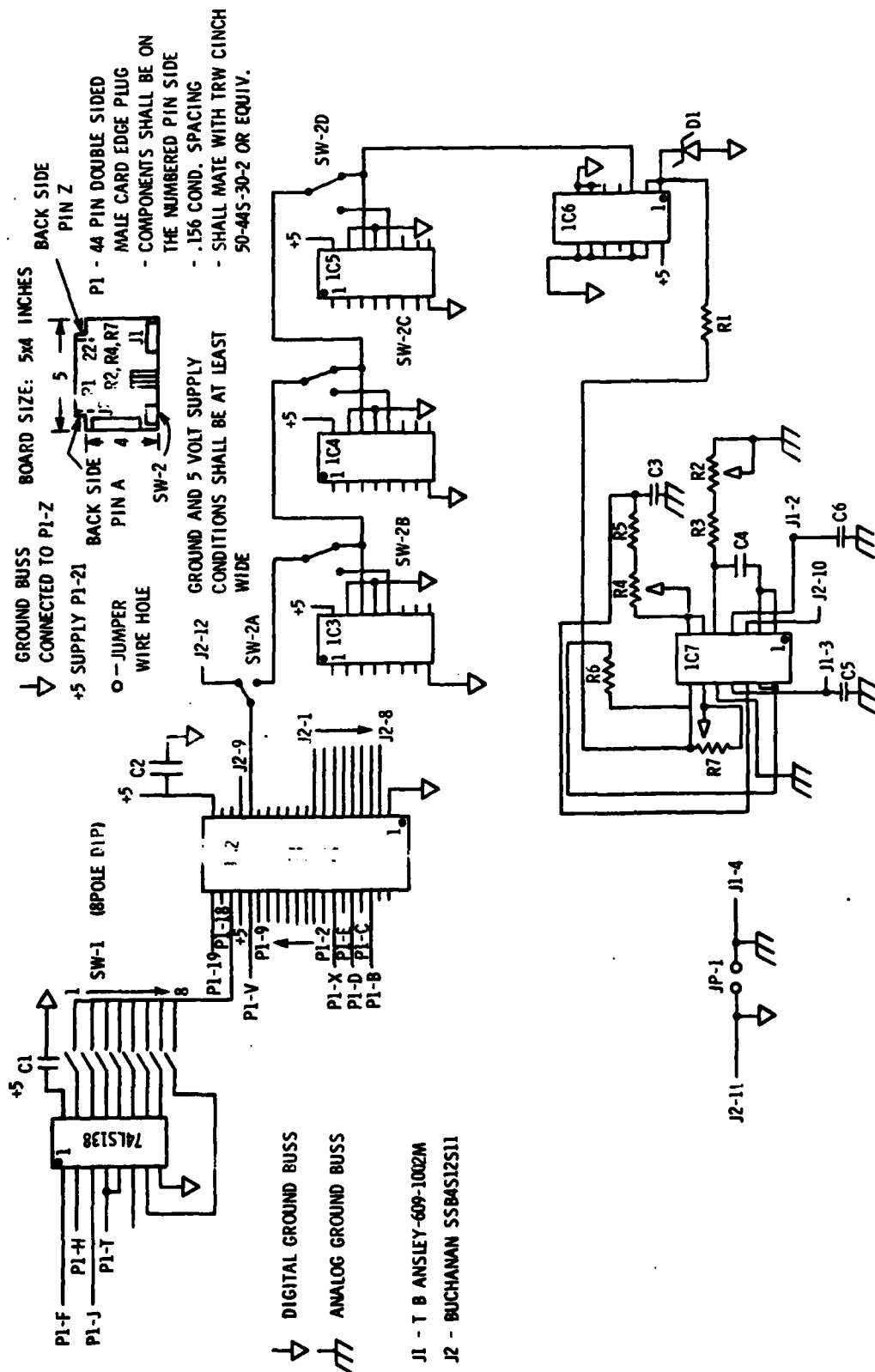
DIGITAL GROUND BUSS CONNECTED TO P1-Z  
 +5 SUPPLY P1-21  
 0 - JUMPER WIRE HOLES  
 P1 - 44 PIN DOUBLE SIDED MALE CARD EDGE PLUG  
 COMPONENTS SHALL BE ON THE NUMBERED PIN SIDE  
 .156 COND. SPACING  
 SHALL MATE WITH TRW CINCH 50-44S-30-2 OR EQUIV.  
 P2 - 0.1 INCH CENTER PC WIRE WRAP PINS  
 GROUND AND

BACK SIDE PIN A  
 BACK SIDE PIN Z  
 J1  
 J2

**BOARD SIZE: 5 x 4 INCHES**

**GROUND AND  
5 VOLT SUPPLY COND'S.  
SHALL BE AT LEAST 1/16 WIDE  
J1 - T + B ANSLEY 609-1002M  
MOUNIED OPPOSITE P1  
J2 - BUCHANAN 55B4S4S11  
TERMINAL STRIP**

# VIC-20 COUNTER/TIMER/DIO BOARD 830729





4

3

2

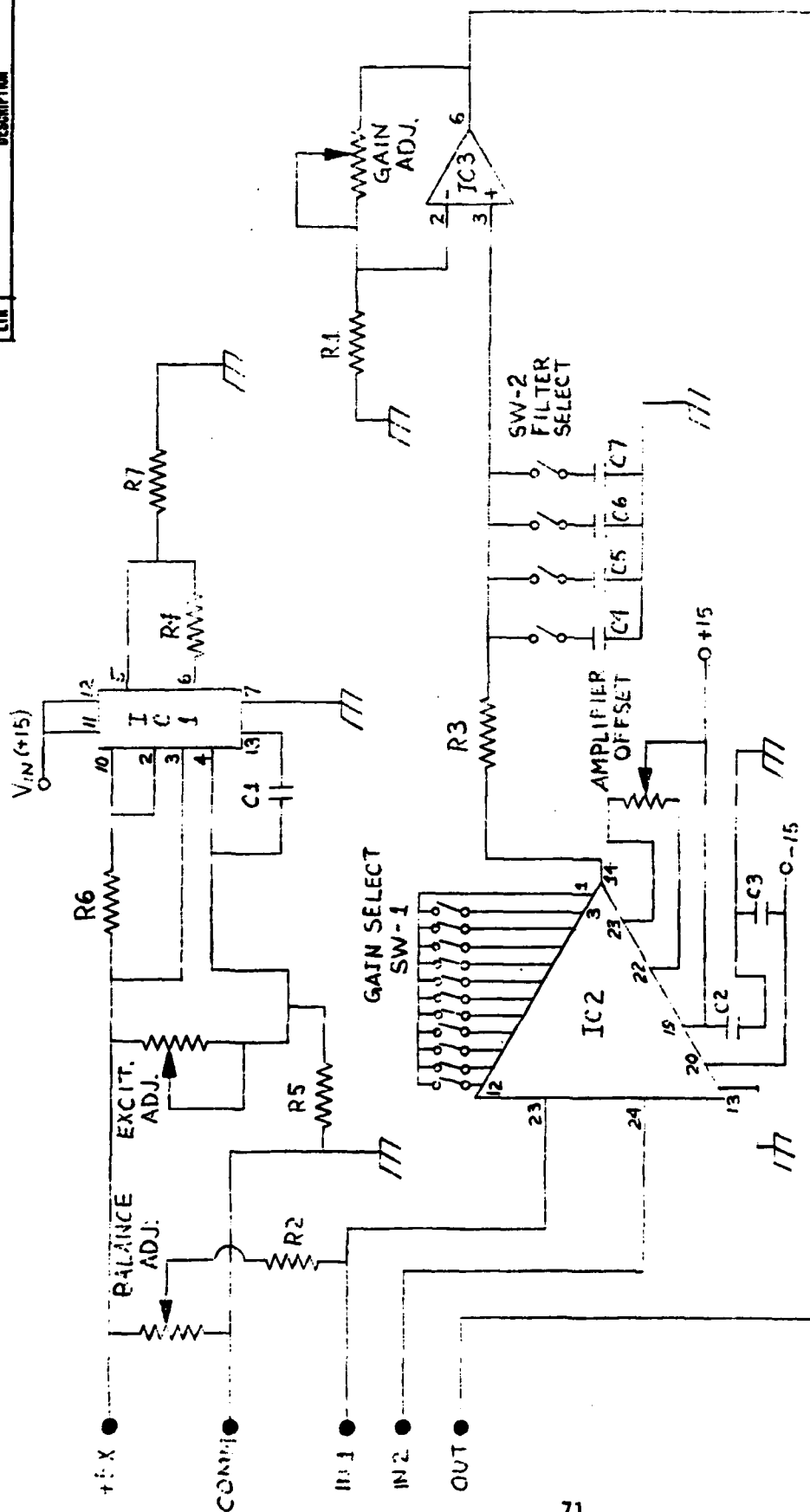
1

## REVISIONS

DESCRIPTION

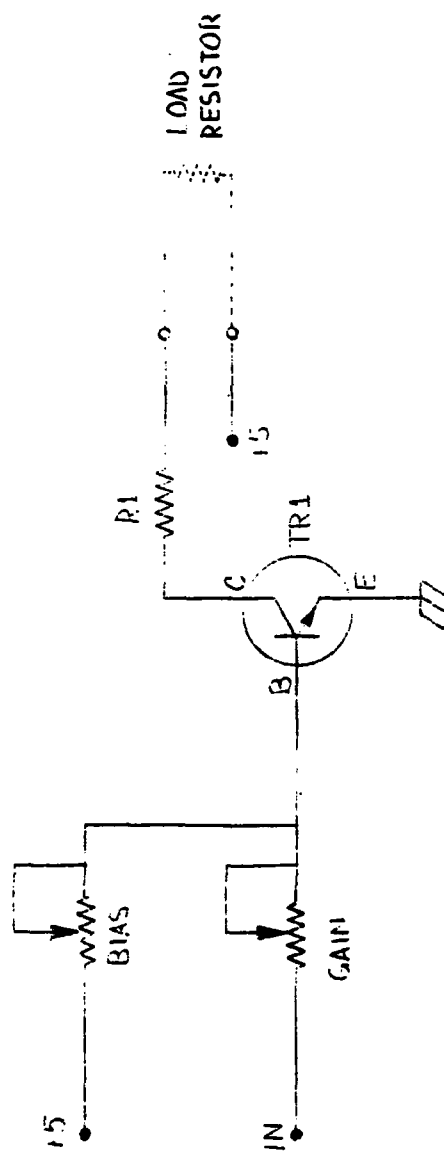
LIT

MI



71

QUANTITY REQUIRED PER BOARD NO.	SIN	DESCRIPTION	CORE IDENT	IDENTIFYING NO	MATERIAL / SPECIFICATION	UNIT
<b>PARTS LIST</b>						
<p>WELLS SYSTEMS SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON PLACEMENT DIMENSIONS ARE ±.015 ±.015 ±.015</p>						
<p>U.S. AIR FORCE</p>						
<p>BRIDGE CONDITIONER BOARD SCHEMATIC</p>						
<p>DATE 11/11/65 BY 11/11/65</p>						
<p>SCALE 1/10" = 1"</p>						
<p>ENGINEERING DATA</p>						



4 TO 20 MA CURRENT DRIVER UDRI 840205

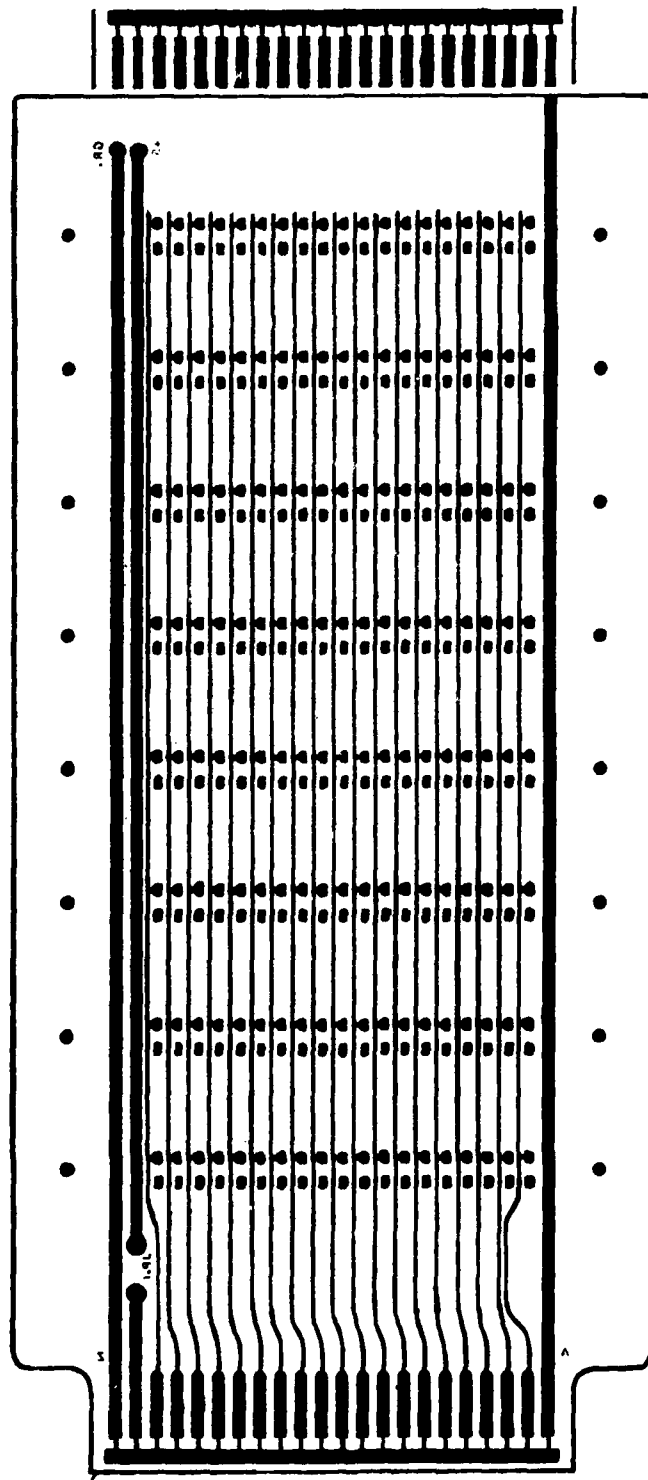
SCALE: NONE



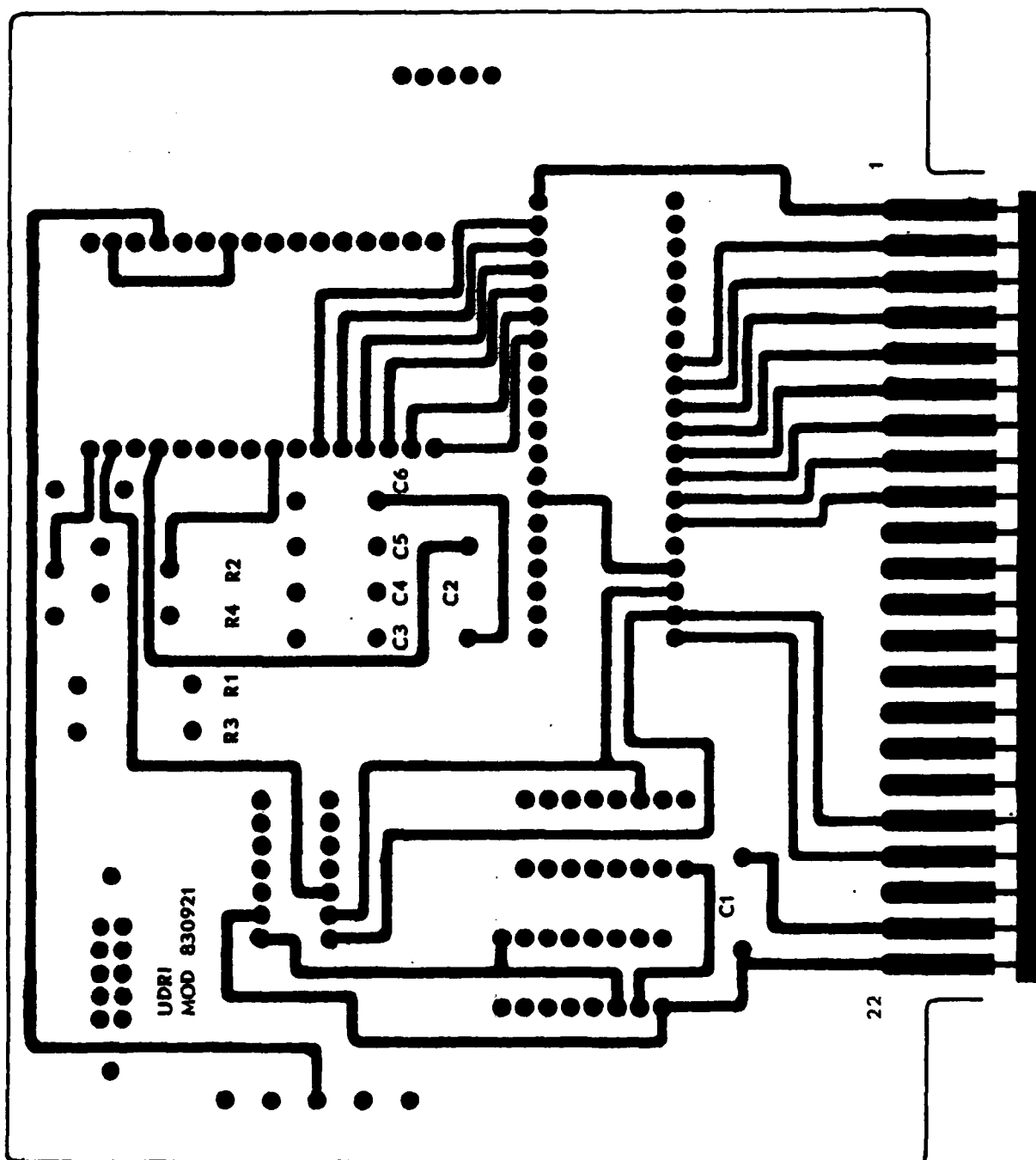
**APPENDIX C**  
**BOARD LAYOUTS FOR THE INTERFACE BOARDS**



BACK SIDE

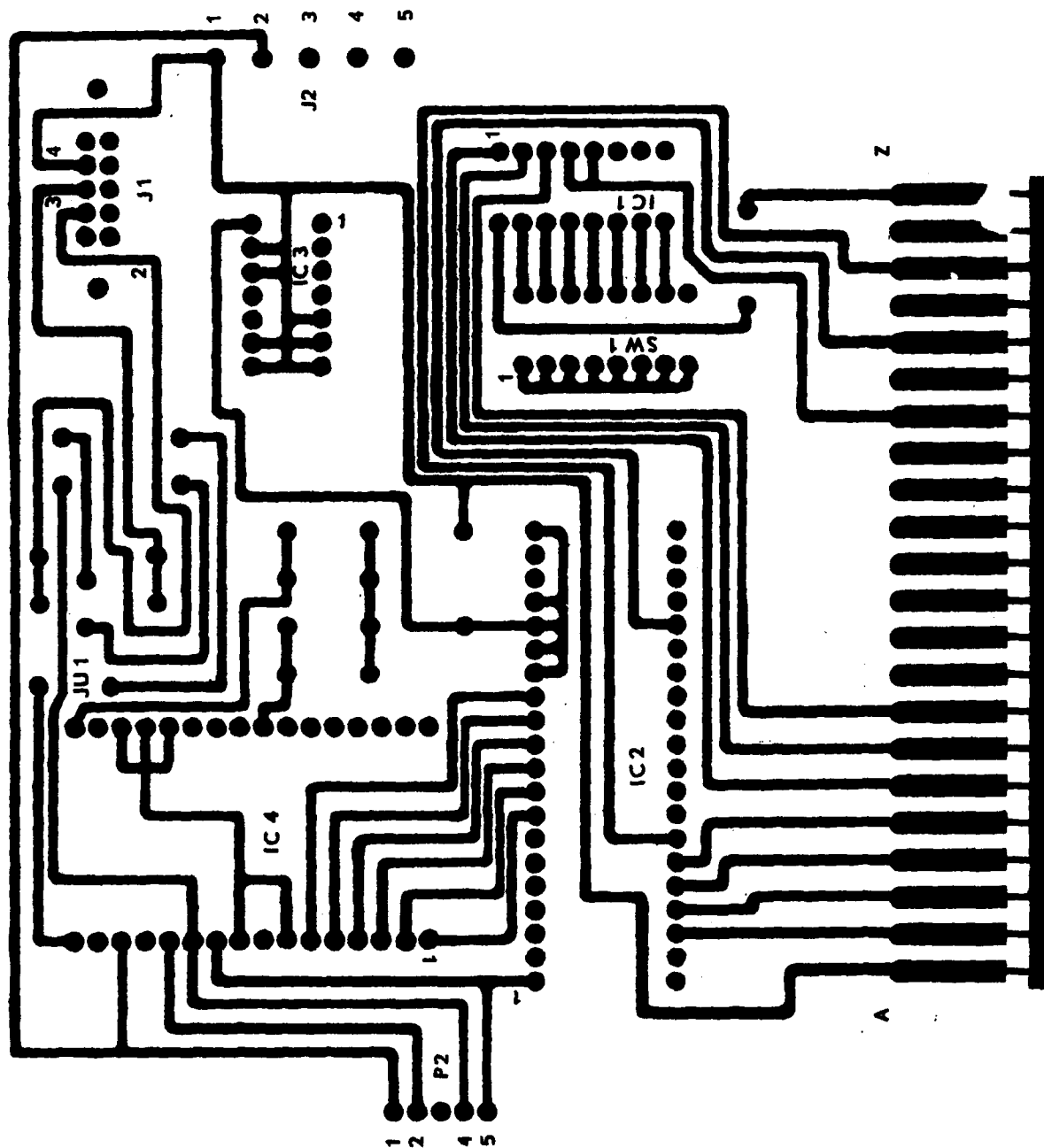


COMPONENT SIDE



A/D CONVERTER BOARD LAYOUT

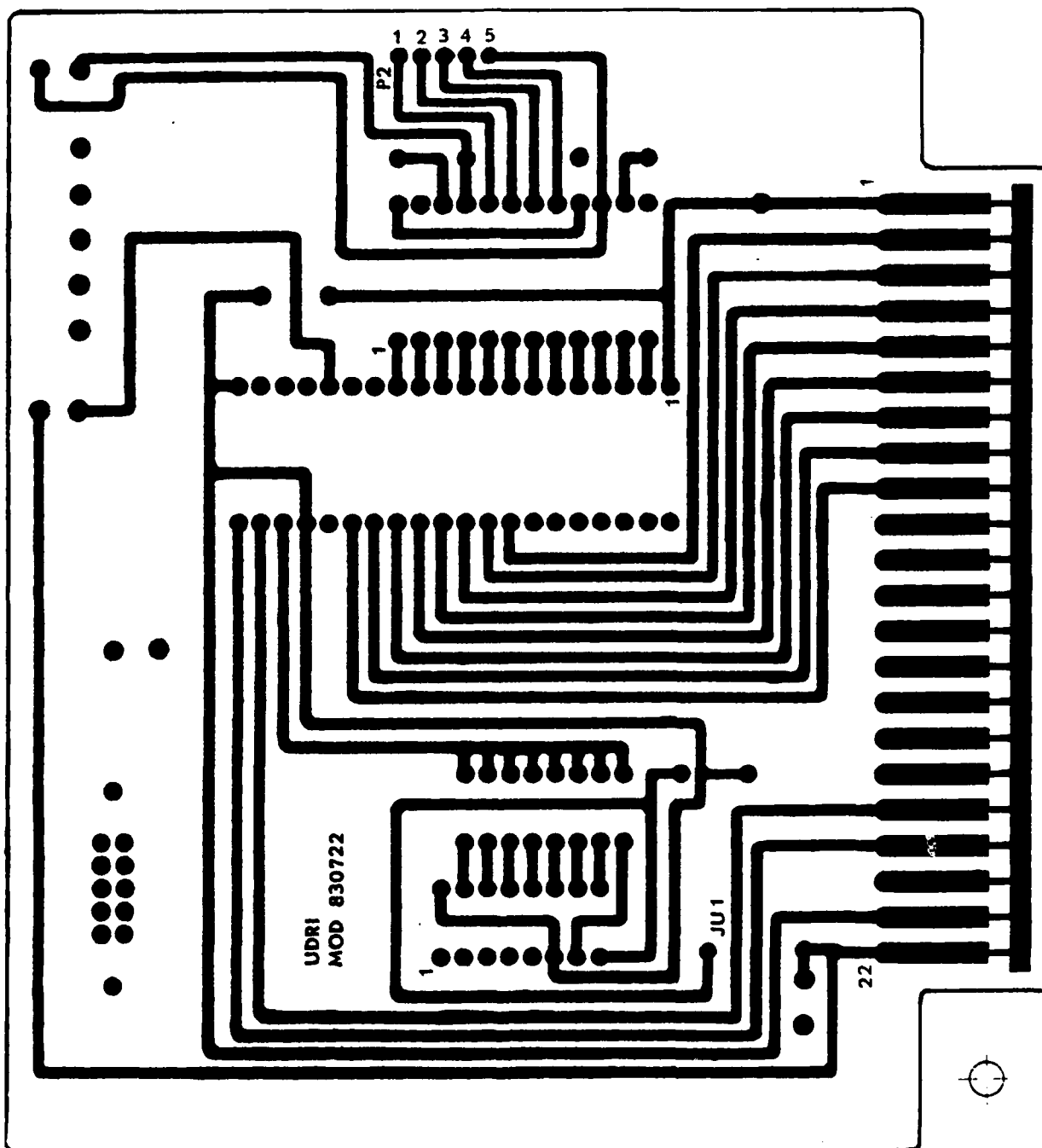
BACK SIDE



A/D CONVERTER BOARD LAYOUT

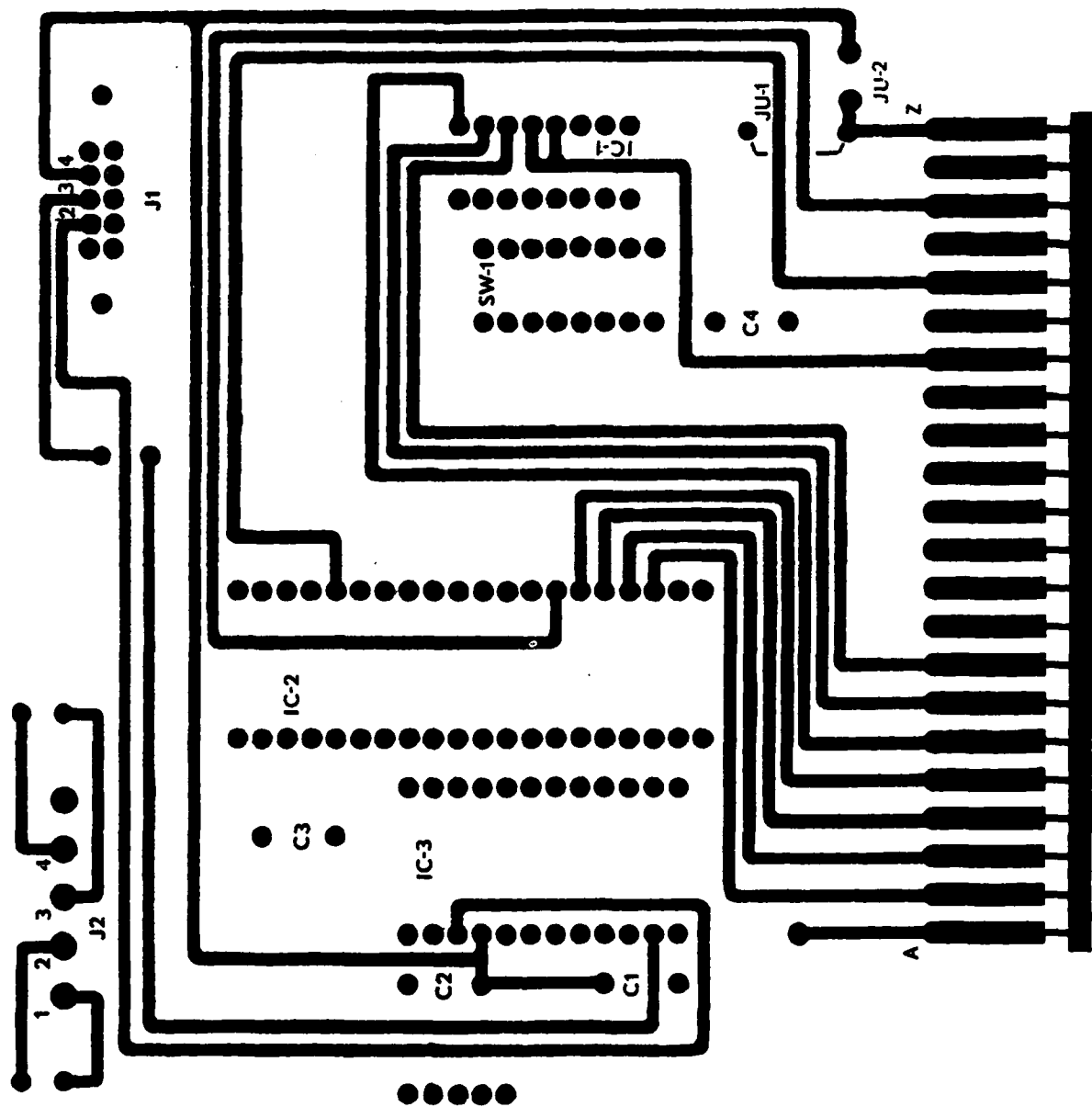


COMPONENT SIDE



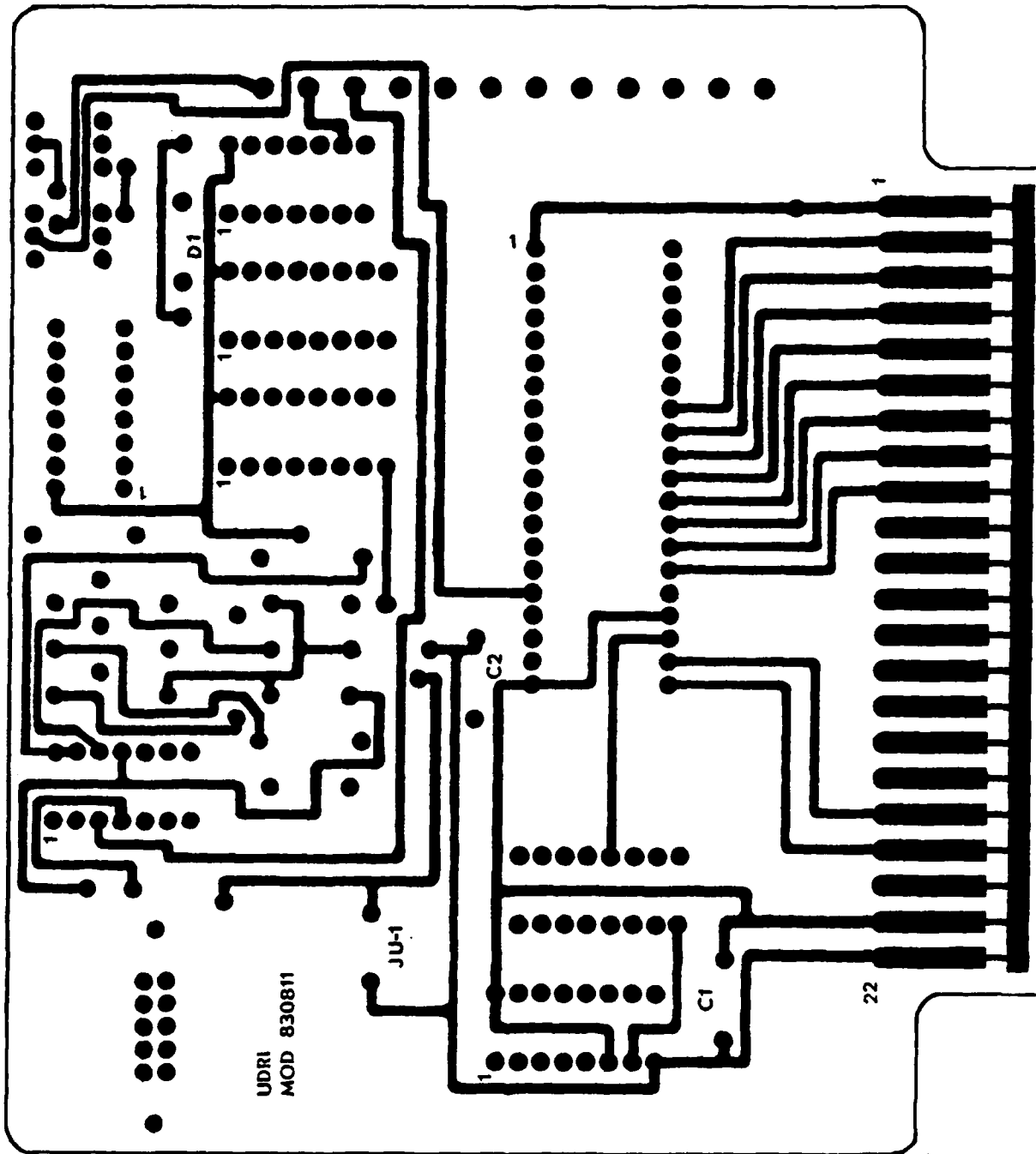
D/A CONVERTER BOARD LAYOUT

BACK SIDE

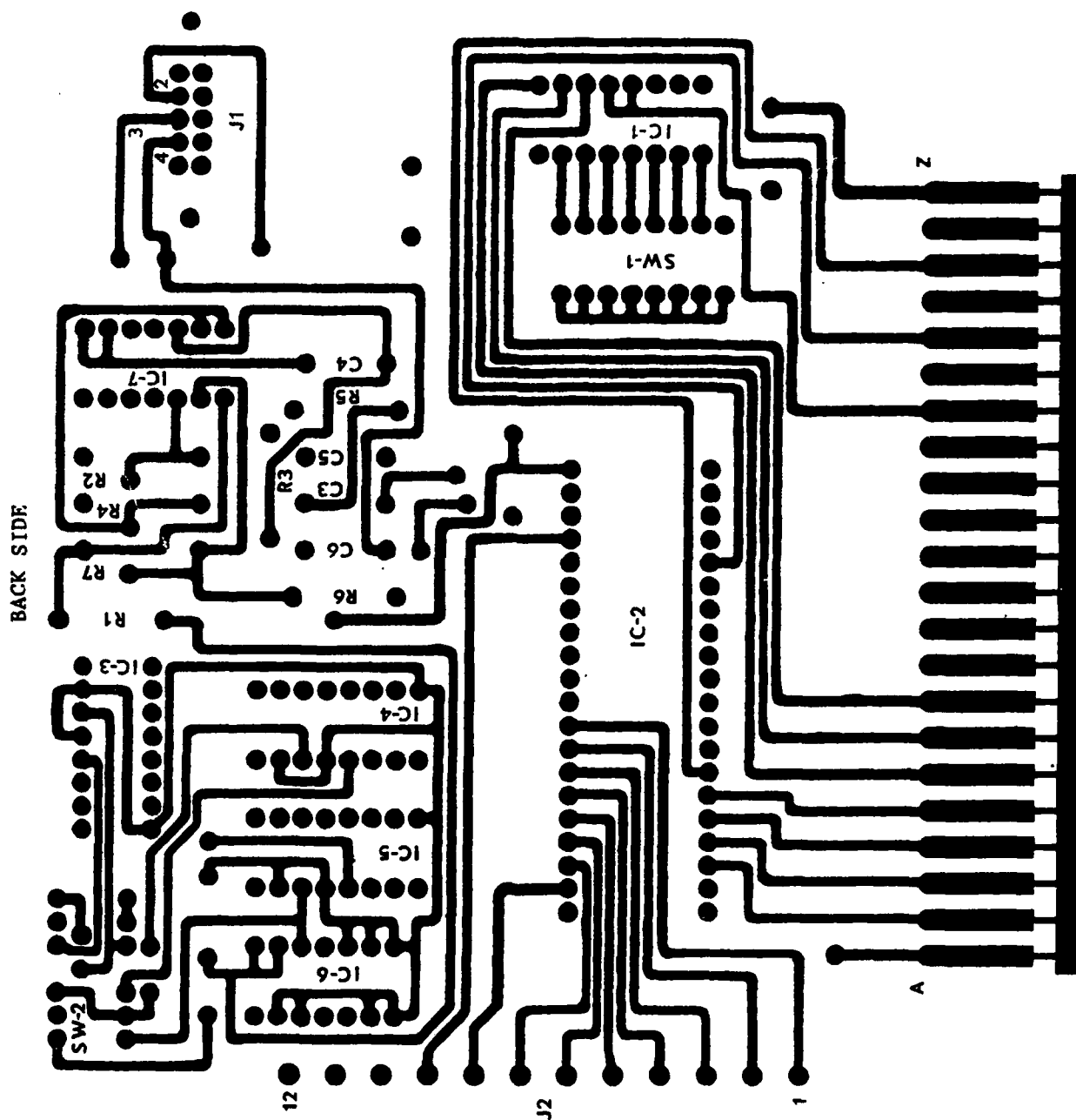


D/A CONVERTER BOARD LAYOUT

COMPONENT SIDE

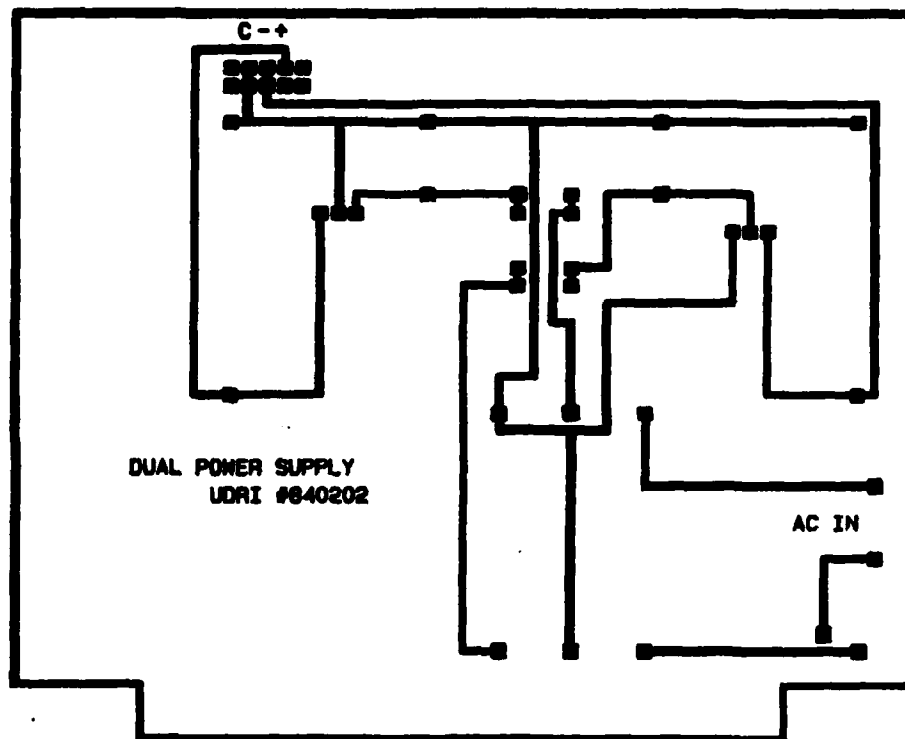


COUNTER/TIMER/DIO BOARD LAYOUT

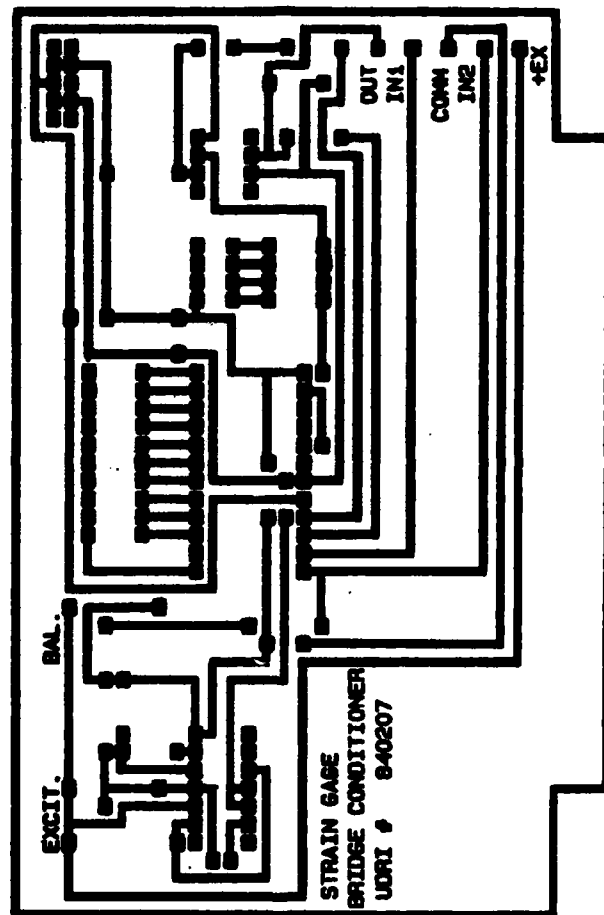


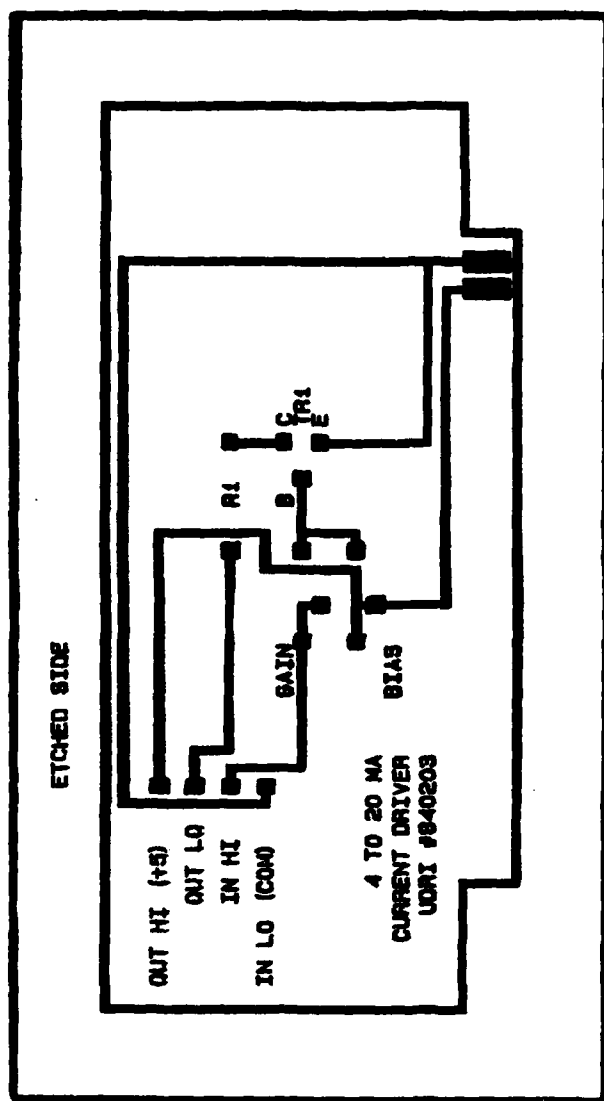
COUNTER/TIMER/DIO BOARD LAYOUT

ETCHED SIDE



ETCHED SIDE





END

FILMED

10-84

DTIC